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Exploring the Role of Explainable AI in Attack Modeling for IoT Networks

Discipline: Computer Science

**Blessy Thomas*

Abstract - In an era marked by the pervasive presence of Internet of Things (IoT) networks, it is critical to ensure the strong security of these autonomous systems. The integrity, confidentiality, and availability of IoT networks are threatened by new, complex security concerns that have arisen as a result of the rapid expansion of these networks. Vulnerabilities in the IoT are often exploited by the attacker to gain unauthorized access endangering privacy and security of the network. Identifying potential attack paths in the connected ecosystem is essential for implementing strong security measures. With attack modeling, security experts can evaluate the potential attack paths in the network. We propose a new framework for attack modeling in IoT networks by incorporating Explainable AI(XAI). The XAI algorithm LIME (Local Interpretable Model Agnostic Explanations) has been included in the proposed framework to enhance the explanation and comprehension of the critical attack paths predicted. A use case is discussed and various graphs with explanations are provided to evaluate the performance of the attack model against the evolving dynamics of the IoT network. XAI provides a crucial layer of defense for protecting IoT networks from cyber hazards by offering interpretable insights into strong security decisions.

Index Terms - Machine Learning, Deep Learning, Explainable AI, IoT Network Security, Vulnerability Analysis, Attack Mod- elling.

I. INTRODUCTION

The Internet of Things (IoT) unifies billions of intelligent objects that connect with little to no human involvement [1]. Smart bulbs, cameras, televisions, and competent vacuum cleaners are a few of the everyday IoT devices that are linked to home and enterprise networks. This leads the network to become an easy target for attackers, who can readily hide their fraudulent actions among the amounts of data [2]. Most organizations have made significant investments to protect their data and networks from external and internal threats, by implementing sophisticated strategies [3]. The dynamic and quickly changing nature of these attacks makes it difficult for traditional

cybersecurity techniques to keep up. The potential attack surface for attackers grows tremendously as IoT devices become an essential component of our residences, workplaces, factories, and even vital infrastructure. The risks are wide- ranging and constantly changing, ranging from unauthorized access and data breaches to device manipulation and Denial- of-Service (DoS) attacks. Therefore it is ineffective to implement security measures such as encryption, authentication, access control, network security, and application security for IoT devices and their underlying vulnerabilities. To effectively safeguard the IoT ecosystem, it is crucial to enhance existing security techniques. This is where the power of Machine Learning (ML) and Deep Learning (DL) come into play, heralding a paradigm shift in how we perceive security research within IoT networks.

Attackers often use the easiest paths to get inside the network. After identifying and prioritizing the vulnerabilities, it is important to model the attacker's pathways in advance to prevent all the possibilities of an attack [4]. Graphs can effectively illustrate vulnerability relations in a network since they are good at depicting relationships between elements [5]. The use of graphs in attack modeling has prevailed for the last several decades. Several graphical representations, such as attack graphs [6], attack trees [7], and attack-defense trees [8], are in use. Among these attack models, attack graphs are most widely used in representing vulnerability relations. The attack graph can show the attacker's paths to reach the desired system state [6]. DL and ML can assist with the automatic generation of attack graphs based on system parameters and recognized vulnerabilities promise to transform the cyber security environment.

Although ML and DL models excel, it can be difficult for human operators to trust and comprehend their judgments because of the intricate and opaque inner workings. XAI serves as a link between cutting-edge AI methods and human cognition. XAI promotes trust and accountability in IoT security by offering visible and comprehensible justifications for the decisions made by ML and DL models.

The concept of XAI gained prominence in the early 21st century as researchers and practitioners recognized the importance of developing AI models and techniques that could provide understandable and transparent explanations for their decisions.

Since then, XAI has evolved rapidly, with various methods and frameworks designed to enhance the interpretability of AI systems, making them accountable, ethical, and applicable in domains where human comprehension is critical. With a large number of networked devices, protocols, and configurations, IoT ecosystems can be extremely complex. Without adequate justifications, it might be difficult to comprehend the risks and vulnerabilities in such environments. To provide interpretable insights into the vulnerabilities found and their possible effects, XAI can simplify the complexity of interpreting traditional attack modeling.

Local Interpretable Model-Agnostic Explanations (LIME), a potent XAI algorithm, holds significant importance in improving the clarity and interpretability of complicated machine learning and deep learning models [30]. Incorporating this XAI algorithm in attack modeling enables organizations to make wise choices on countermeasures, strengthen their security posture, and successfully address vulnerabilities in their IoT networks.

The rest of the paper is organized as follows, in section II we discuss the related works which include the role of ML and DL in IoT security, the importance of XAI in IoT network security, and attack modeling. In section III we explore the role of XAI in attack modeling and address the dynamic features of IoT. The proposed framework is explained in section IV and section V discusses the case study we conducted. The conclusion and future works are presented in section V.

II. RELATED WORKS

In this section, we discuss the prominent works in IoT network security that use ML and DL. Further, we discuss the importance of XAI in securing IoT networks and the existing attack modeling techniques.

a. ML and DL for IoT network security

IoT vulnerability assessment locates and resolves security flaws or vulnerabilities inside IoT ecosystems. It includes the identification and prevention of potential attack vectors that might take advantage of these weaknesses. Traditional attack detection

and mitigation strategies rely on cryptographic primitives, which can occasionally be inaccurate and result in false positives, which demands the need of ML-based methods. The proposed method in [9], MANDRAKE, aims to detect vulnerabilities in IoT network traffic by analyzing packet traffic using machine learning techniques. This analysis helps identify potential vulnerabilities in traffic encryption, which is essential for ensuring the security of IoT networks. Similarly, LNKDSEA, a hybrid ensemble algorithm that efficiently identifies various types of attacks in IoT networks, including DDoS, information gathering, malware, injection attacks, and man-in-the-middle attacks is introduced in [10] LNKDSEA combines Logistic regression, Naïve Bayes, K-nearest-neighbour, Decision tree, and Support Vector Machine to achieve high performance in detecting cyberattacks in both binary and multi-class classifications. The authors in [11] propose a solution for detecting and classifying attacks on IoT networks using novel ensemble techniques, CatBoost and XGBoost, trained on the realistic Edge-IIoTset Dataset. A distributed attack detection technique for IoT utilizing a deep learning approach was suggested in [12]. By employing deep learning techniques, the strategy seeks to identify assaults in IoT networks. Twenty Raspberry Pi IoT devices that had been infected were used by the authors in their studies, and they were successful in detecting attacks with an accuracy of 96 percent. The authors in [13] discuss the challenges of cybersecurity in IoT and propose a novel distributed deep learning scheme for cyber-attack detection in fog-to-things computing. The proposed approach concentrated on fog-to-thing communication and implemented the learning module at the fog layer, which is the best place for a detection mechanism because it both decreases communication latency and makes use of the available resources. The accuracy of the proposed three-layer stacked autoencoder is 99.2 percent. Hybrid deep learning models, which combine different deep learning techniques, are gaining attention for improving the detection of cyber-attacks in IoT networks. The authors in [14] propose a hybrid deep learning model using CNN and LSTM for detecting attacks in IoT devices with an accuracy of 96 percent.

b. Explainable AI for IoT network

In IoT networks with critical application infrastructures to foster trust, it is crucial to comprehend how AI-based security systems make judgments. In high-risk

circumstances, transparency is crucial, and XAI offers it by outlining the rationale behind and process of each security decision and action. In [15] authors apply XAI to generate explanations for incorrect classifications made by data-driven Intrusion Detection Systems (IDSs). An adversarial approach is used to find the minimum modifications required to correctly classify misclassified samples, and the magnitude of these modifications is used to visualize the most relevant features that explain the reason for the misclassification. XAI is used in the context of secure Cloud-Edge deployments to provide explainable assessments of the security level of IoT applications in [16]. The methodology presented in the paper allows for automatically obtaining an explainable assessment of the security level of possible application deployments. XAI helps in expressing security requirements for IoT applications and infrastructure security capabilities in a simple and declarative manner. The authors in [17] advocate for the integration of domain knowledge into XAI models. By incorporating domain-specific expertise, XAI-enhanced IDR systems aim to provide more transparent and interpretable intrusion detection outcomes, thus enabling security analysts to better understand the rationale behind security alerts and facilitate more effective response strategies. In [18] authors introduce an innovative framework that combines deep learning techniques with explainability mechanisms. This framework not only provides effective intrusion detection but also offers transparent and interpretable results, allowing security professionals to understand the rationale behind detected intrusions. By leveraging the power of deep learning while ensuring explainability, this research contributes to the advancement of IoT security, addressing the growing need for robust and understandable intrusion detection systems in IoT ecosystems.

Security experts can benefit from using XAI to better understand the types of vulnerabilities and attacks that can occur in IoT networks. It offers insights into the attack patterns and provides justifications for security alerts. XAI assists in adjusting security measures by outlining the dangers and vulnerabilities particular to each IoT environment.

C. Attack modelling

In attack modeling, attack graphs are important for locating and visualizing

probable attack paths that an attacker could use to breach a system. Security experts can better understand the security posture of their systems and spot possible vulnerabilities that can be fixed to increase overall security by analyzing attack graphs. In [19] the authors introduced the idea of attack graphs and suggested an automated process for creating and analyzing them, which is a significant contribution to cybersecurity. The methodology consists of three basic steps: modeling the network, modeling the abilities and goals of the attacker, and creating the attack graph. The authors use formal methods, such as model checking, to verify the correctness of the generated attack graph.

The automatic generation and analysis of attack graphs is now necessary for defending IoT systems. Automated generation and analysis of attack graphs make use of machine learning and deep learning techniques to find emerging dangers and weaknesses in the IoT ecosystem. Machine learning and deep learning techniques enable real-time monitoring, rapid threat response, and proactive defense, making the automatic generation and analysis of attack graphs indispensable for safeguarding IoT systems against cyberattacks. The authors in [20] propose a methodology for building attack circuits that uses input/output pairs created by Natural Language Processing (NLP). The weights are also calculated using conventional security score metrics, and attack circuits are assessed using effective optimization methods. The contribution consists of a methodology that analyses possible attack vectors depending on their impact, exploitability, or overall risk. The authors use Fuzzy Petri Net (FPN) to establish an attack model and improve Q-Learning through FPN in [21]. They define the attack gain from the attacker's perspective to determine the best attack path. The paper introduces a quantitative indicator for analyzing the impact of cyber attacks on the real-time operation of power grids. The contribution is an attack model that enhances a Q-Learning algorithm with the use of FPN's fuzzy reasoning capabilities and further uses the Q-Learning algorithm to identify the network system's vulnerable part. An Autonomous Security Analysis and Penetration testing framework (ASAP) that uses attack graphs to identify security threats and attack paths in a network is introduced in [22]. The framework incorporates a state-of-the-art reinforcement learning algorithm based on Deep-Q Network (DQN) to determine the optimal policy for performing penetration testing. It also includes a domain-specific transition matrix and reward

modeling to capture the importance of security vulnerabilities and the difficulty in exploiting them. The ASAP framework generates autonomous attack plans and validates them against real-world networks, making it applicable to complex enterprise networks. The attack involves injecting a predefined subgraph into a testing graph, causing the GNN classifier to predict an attacker-chosen target label for that graph. The attack is shown to be effective with minimal impact on the GNN's prediction accuracy for clean testing graphs.

In dynamic IoT networks, attack modeling is an ongoing process that changes as the network changes. It helps organizations proactively identify and address security issues, safeguard IoT assets, and preserve the dependability and integrity of IoT services. An approach for enhancing the security of Internet of Vehicles (IoV) systems through the creation of dynamic attack graphs using ontology-based techniques is introduced in [23]. To capture dynamic features of cyberattacks, such as conditional dependencies, time-sensitive actions, and the effect of countermeasures, the authors introduce a formal framework for building Dynamic Attack Trees [24]. With this method, it is easier to evaluate and respond to evolving real-world cyber threats.

In [26] provides a complex method of assessing cybersecurity risk through the use of dynamic attack graphs based on logic. These attack graphs offer a potent way to analyze and assess security risks in intricate computer systems. Dynamic logic-based attack graphs, as opposed to static attack graphs, can reflect the changing nature of cyberattacks by taking into consideration the actions of the attacker, vulnerabilities, and the long-term effects of security countermeasures. By enabling more precise and rapid assessments of potential threats and vulnerabilities, this dynamic approach improves risk assessment. As a result, the security posture of complex computer systems in the face of changing cyber hazards is eventually improved.

All the works in attack modeling mentioned above fail to address all the features of dynamic IoT networks. There is no proper explanation for generating new attack graphs over time. Incorporating XAI into attack modeling and addressing the dynamic nature of IoT networks aids defenders in identifying the root causes of vulnerabilities in each network scenario. Defenders can take specific action to address these changes in attack paths to prevent any further attacks.

III. ROLE OF XAI IN ATTACK MODELING FOR DYNAMIC IOT NETWORK.

a. Addressing the dynamicity of IoT network

In applications and situations where IoT devices and their interactions are frequently changing and where adaptability, scalability, and effective resource management are crucial, dynamic IoT networks are well suited. Realizing the full promise of IoT in fields like smart cities, industrial automation, and healthcare requires these networks. Some of the important features of IoT networks are described below [25], [23], [27], [28], [29].

1. *Device Diversity:* IoT networks are made up of several types of devices, from basic sensors to strong gateways and edge devices, all with different kinds of capabilities. The vulnerabilities and weaknesses of various IoT devices can vary.
2. *Topological Changes:* Due to the mobility of devices or the addition/removal of devices, IoT network topologies can change regularly.
3. *Raising and patching of Vulnerabilities:* As few devices will be removed from the network some of the vulnerabilities will be patched over time. Similarly, when new devices are introduced into the network new vulnerabilities may arise.
4. *Change in connectivity:* When devices are joined and removed the connectivity between the devices will change according to the change in the firewall rules.
5. *Communication protocols:* In dynamic IoT networks, where devices might join, depart, or move within the network, require different communication protocols. For instance, a new IoT device can negotiate with the network infrastructure to choose the appropriate protocol for data exchange when it enters the network.

These key reasons make the dynamic IoT network crucial and thereby a different attack modelling strategy is needed. It is imperative to use XAI in attack modeling for IoT networks to improve the security of these networked systems.

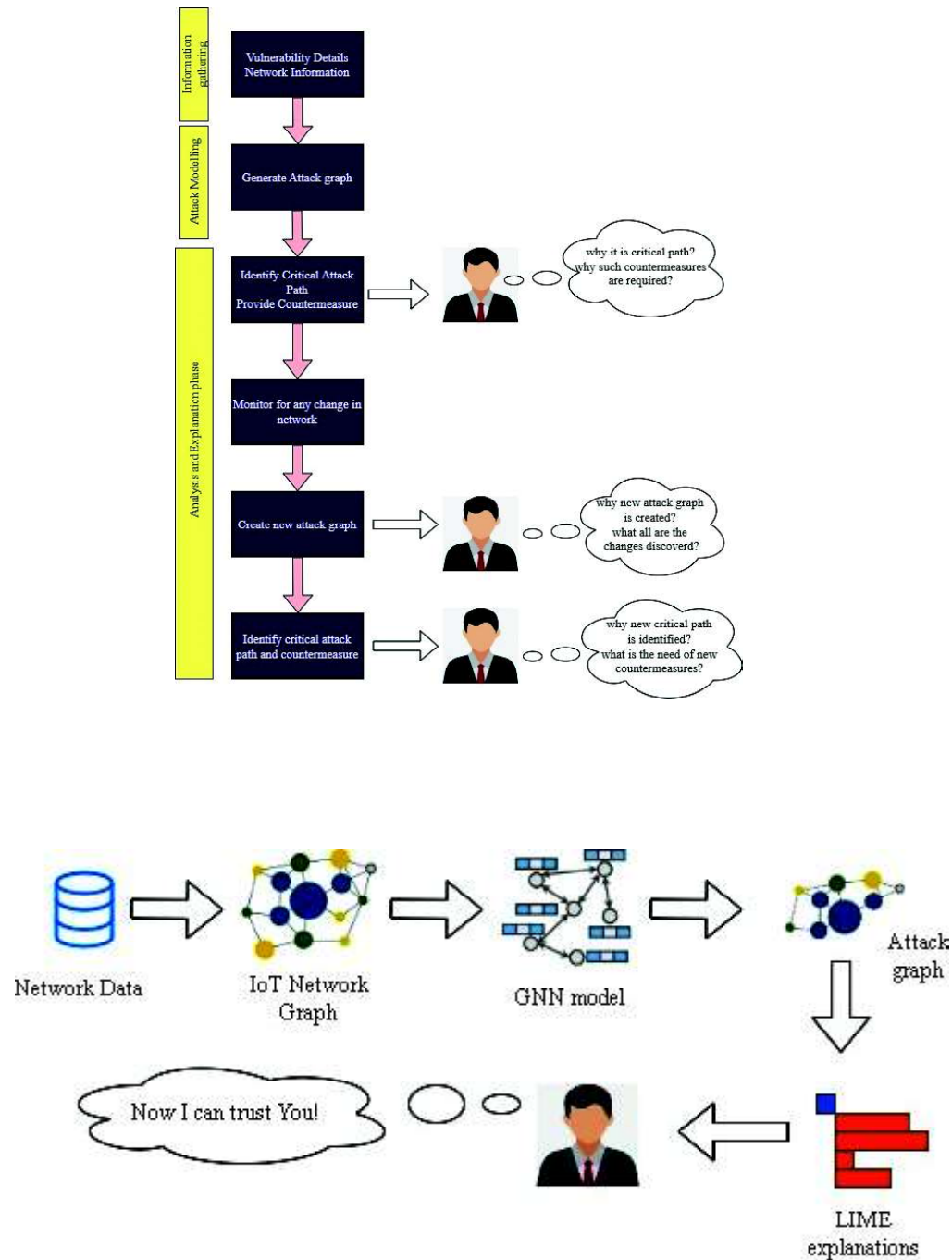
B. Incorporating XAI in attack modeling

Dynamic IoT networks have a constantly changing network scenario, which frequently introduces new attack surfaces and attack paths [28]. So the network defenders should eagerly monitor for any change in the network. If the defender fails to identify any of the critical attack paths or provides incorrect countermeasures, the consequence will have far-reaching impacts. This is where XAI is required, XAI provides transparency and trust for identified attack paths and counter-measures.

1. *Better Understanding of change in the network and attack graph:* The ML model will continuously monitor for the change in the network and if any changes are identified new attack graph is generated. XAI will explain the need for a new attack graph and what are the changes that occurred in the network and attack graph compared with the previously generated one.
2. *Explainability regarding attack paths:* XAI will explain the reason for the existence of attack paths which is the most critical attack path and which features influenced the finding. With this explanation, the defenders will get a better knowledge of the possible attack scenarios which further helps in improving the security posture of the network.
3. *Transparency of countermeasures:* After the critical path is identified ML will provide suitable countermeasure strategies and the XAI will help to understand why a specific decision for a particular countermeasure is taken. It assists to discover and address potential problems with AI, such as accountability, bias, and discrimination.

IV. PROPOSED FRAMEWORK

We propose a new framework that uses Explainable AI to enhance transparency in the generated attack graph and countermeasures provided. Figure 1 shows the proposed framework.



Our framework consists of three phases:

1. *Information Gathering:* The network is scanned to find any existing

vulnerabilities using network analyzer tools like Nessus, Retina, Open-VAS, and Nexpose. The information acquired in this initial stage offers a thorough picture of the system's resources, network layout, and potential vulnerabilities. The features and severity of the discovered vulnerabilities are then determined using the NIST Common Vulnerability Scoring System (CVSS) base metrics [32].

2. *Attack Modelling:* An IoT network graph is created with the data acquired in the information-gathering phase. Graph Neural Networks (GNNs) are appropriate for simulating attack pathways in network graphs as they can capture node and edge associations and are capable of learning the network structure information [31]. The graph's nodes and edges should include additional properties or attributes to provide the GNN with meaningful information for predicting attack paths. These attributes include device types, vulnerability information, firewall settings, and other relevant network information. Further GNN represents these predicted attack paths as an attack graph.
3. *Analysis and Explanation:* In this phase, the generated attack graph is used for the analysis and identification of critical attack paths. The reason for selecting an attack path as critical involves several reasons including the probability of attacker reachability, diversity of exploits in the paths, ease of exploiting vulnerabilities, and so on. With the help of the XAI LIME algorithm, we could get insights regarding why the path is critical, which are the appropriate countermeasure strategies to be applied, and why it is necessary to provide such countermeasures. Figure 2 shows the creation of the attack graph with GNN and LIME explanations.

Again in this phase, the framework monitors for any change in the network, the change can be identified via the parameters specified in section III A, if the change is noticed, a new attack graph is created and XAI will explain the changes that occurred and why the new graph is created. Again, from this newly created attack graph, the critical attack path in the attack graph is identified either with the help of any counting or difficulty-based metrics and further, the countermeasures are provided.

V. CASE STUDY

In our case study of the most popular IoT network which is Internet of Drones (IoD) network, a leader drone serves as a central node, managing communication with GCS and other IoD. Figure 3 shows the example IoD network. For effective data exchange and decision making, the leader drone can communicate with edge devices. Moreover, the network integrates edge computing capabilities, allowing edge devices to communicate with cloud services for secure storage of sensitive data.

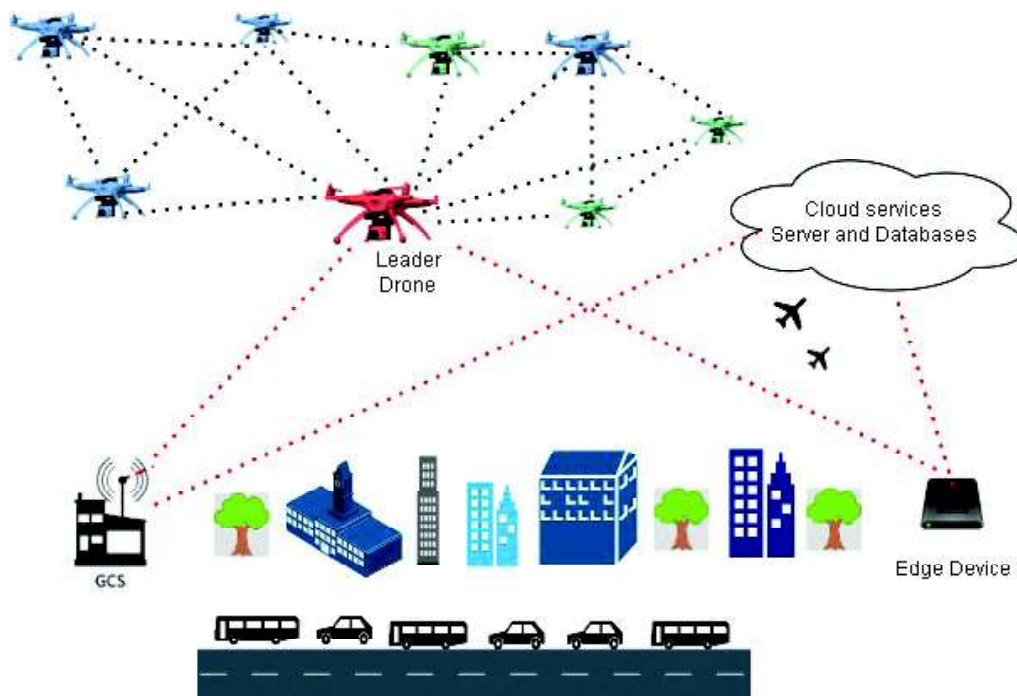


TABLE I
TOP FEATURES FOR IDENTIFYING NETWORK CHANGE

Features	Definition
firewall rules	Change in firewall rules of the network.
mobility	Mobility of Drone in the network.
protocol	Changes in the network protocols.
throughput	Change in throughput.
network density	Changes in the number of Drone in the IoD network.
topology change	Topological changes in the network.
latency	Change in latency.

Due to the absence of real-world data, we employed Monte Carlo simulation to generate a synthetic dataset. We validated the simulation process by comparing the results with established models to ensure that the approach is in line with pre-ailing best practices in IoD network analysis. Figure 6 shows the different possible attack paths from our IoD network. The features used for identifying the critical attack paths are shown in Table II.

TABLE II
TOP FEATURES FOR IDENTIFYING CRITICAL ATTACK PATH

Features	Definition
patch status	The existence of vulnerability in the network.
useraccess rights	Access rights of a user in the network.
cvss	Associated CVSS score for each vulnerability.
prob exploited	Probability of exploits being attacked.
diversity	Type of vulnerability in the attack path.
pathlength	Length of the attack path.
target	Attacker reachability to any of the targets in the network.

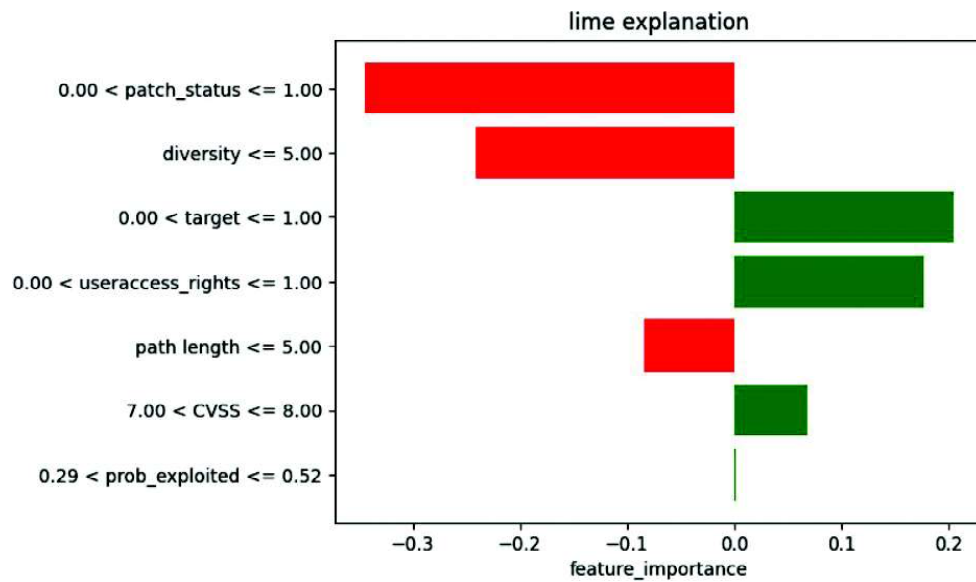


Fig. 4. Feature importance for predicting critical attack paths

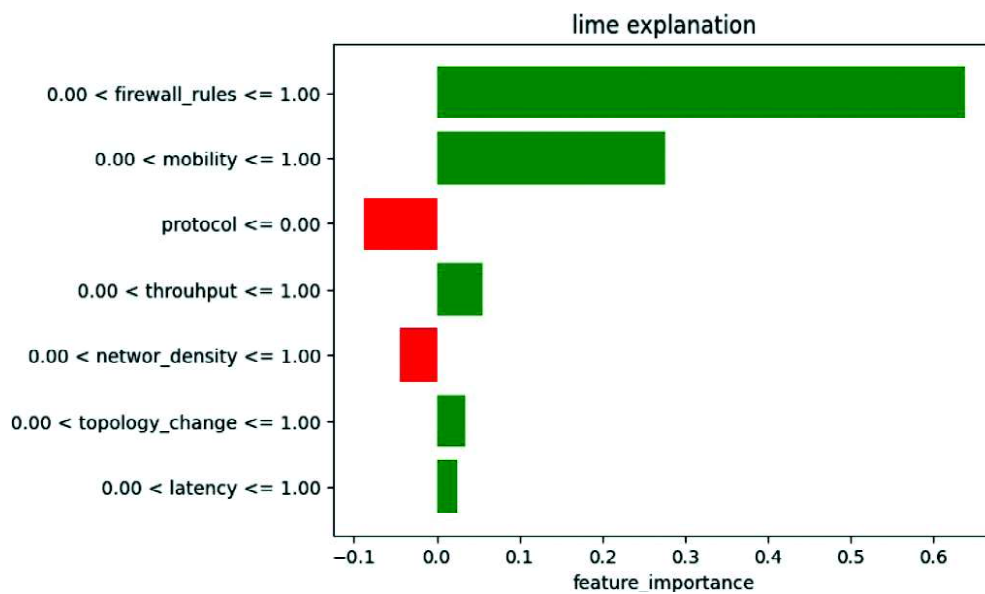
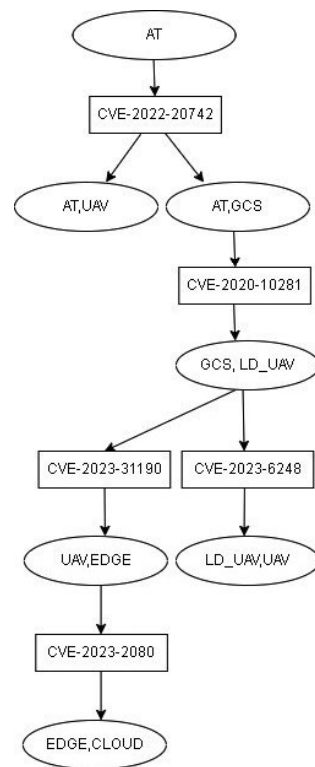


Fig. 5. Feature Importance for predicting network change

The importance of features contributing to the prediction is shown in Figure 4 is identified using LIME algorithm. The figure summarizes the high CVSS score, user access rights, target reachability, and the probability of exploitation as factors that positively contribute to predicting the specific path as crucial.

The model keeps monitoring the network for any change. LIME gives the importance of features contributing to identifying the change in the network. The features used for identifying network change are shown in Table I. The importance of features that address the dynamicity is shown in Figure 5. Predicting network changes is aided by updates to firewall rules, the high mobility of Drone with topological changes, and variations in throughput and latency positively contribute to predicting network change.

**Fig. 6. Attack graph**

As the network changes, the model continues to generate new attack graphs with explanations that assist in maintaining network security.

I. CONCLUSION AND FUTURE WORKS

It has become clear from our exploration of the dynamic and interconnected nature of IoT ecosystems that conventional security methods are insufficient to address the changing threat scenario. It is impossible to overestimate the importance of ML and DL for IoT security but there is a need for justifications for the decisions taken. In this conflict, XAI technologies have proven to be essential weapons, enabling us to identify threats and take action with unprecedented speed and accuracy. In a constantly changing network, XAI provides defenders with actionable information, transparency, and a deeper understanding of attack paths. Beyond technological advancement, the importance of securing IoT networks is fundamental to protecting key infrastructure, guaranteeing data privacy, and promoting confidence in the IoT's revolutionary potential. The paper will act as a starting point for further investigation, pushing the limits of what is feasible in the field of IoT security. We hope that this paper will encourage readers to learn more about this dynamic area, revealing fresh perspectives and stimulating new ideas that will continue to influence the development of secure IoT networks in the future.

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Enhancing Personalization in Recommendation Systems: A Comparative Study of Machine Learning Models on Netflix Data

Discipline: Computer Science

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ABSTRACT—In this research paper the author tries to present a comprehensive study on the development and evaluation of a personalized content recommendation system for the Netflix platform. Various machine learning models were implemented and compared using metrics such as accuracy, recall, F1-score, and precision, to enhance the accuracy and effectiveness of content recommendations. The study encompasses various machine learning techniques, including TF-IDF, Cosine Similarity, Support Vector Machines (SVM), K Nearest Neighbors (KNN), and Nearest Neighbors, to build a hybrid model. The study provides valuable insights into the strengths and limitations of different models applied to the recommendation systems and also enhances personalization by the utilization of hybrid models.

Keywords— Machine Learning, Recommendation Systems, Natural Language Processing, Cosine Similarity, TF-IDF, Support Vector Machines, Comparative Study, Netflix Data.

I. INTRODUCTION

In the digital era, recommendation engines play a pivotal role in enhancing user experience by suggesting products or items based on individual preferences. Widely integrated into commercial websites, these engines leverage metadata and data analytics to understand user behaviour, needs, and interests. Notable platforms like YouTube, Netflix, Amazon, and Pandora employ highly efficient recommendation systems that process extensive data during training stages.

In the ever-expanding landscape of content consumption, recommender systems play a pivotal role in guiding users through the myriad of available choices. This exploration into recommender models revolves around the context of suggesting items related to

the renowned TV series “Breaking Bad.” The diverse range of models employed underscores the multifaceted nature of such systems, revealing the delicate balance between accuracy, relevance, diversity, and novelty.

As we delve into the nuanced performances of various models, it becomes evident that the quest for an optimal recommender system extends beyond mere accuracy, delving into the intricacies of user satisfaction and the fulfilment of diverse preferences. This paper navigates through the strengths and limitations of different models, emphasizing the significance of aligning these systems with the unique requirements and expectations of users in their content discovery journey.

II. LITERATURE REVIEW

This study [1] explores Netflix’s recommender system, emphasizing its evolution from DVD ratings to sophisticated streaming algorithms. Focused on enhancing user engagement, the system targets the challenge of choice overload by delivering personalized recommendations on the Netflix homepage. The review underscores ongoing innovations like global expansion and language awareness, showcasing Netflix’s commitment to refining its recommendation strategies based on extensive user data and experimentation.

In the paper [2] focuses on building a movie recommendation mechanism for Netflix using a dataset of 17K movies and 500K+ customers. It explores popular recommender algorithms like Popularity, Collaborative Filtering, Content-based Filtering, and Hybrid Approaches, aiming to implement and compare them for optimal personalized content suggestions.

This article [3] explores Netflix’s 2006 release of a dataset featuring 100 million anonymous movie ratings. The challenge presented to the data mining, machine learning, and computer science communities was to surpass the accuracy of Netflix’s Cinematch recommendation system. The review briefly outlines the challenge, discusses related efforts, and summarizes the visible progress to date.

The article [4] explores Netflix’s extensive on-demand streaming service available in 190 countries, analyzing 7,787 records. The research includes an examination of

current content trends and introduces a recommendation system using NLP. Despite some limitations, the system shows promise, especially with potential enhancements through additional features.

The paper [5] tells about the Streaming Wars, recommendation systems like Netflix's (NRS) are crucial features for over-the-top video streamers. This article explores the impact of algorithms on taste-making processes, re-evaluating theoretical perspectives. Using a relational materialist approach, the author emphasizes the complex nature of taste-making in the film and television industry.

This paper [6] examines the influence of algorithmic information processing, using the Netflix Prize (2006–2009) as a case study. It argues that beyond its technical goal, the prize aimed to reinterpret the meaning of culture. The essay explores the conceptual challenges in framing algorithmic information processing as a form of cultural decision-making, contributing to the understanding of "algorithmic culture."

I. MACHINE LEARNING TECHNIQUES

There are different Machine Learning Models that can be used to develop a Recommendation System. Based on the data being used you can apply various content-based filtering techniques, collaborative techniques or even the combination of various techniques to build a hybrid model. In this paper, we mainly focus on the different ML techniques like TF-IDF, Cosine Similarity, SVM, KNN and Nearest Neighbor.

a. Term Frequency-Inverse Document Frequency

TF-IDF, a fundamental technique in natural language processing, gauges the importance of a term in a document relative to its prevalence across a document collection. It combines Term Frequency (TF) and Inverse Document Frequency (IDF), assigning weights to terms based on their local and global context.

TF represents the ratio of a term's occurrences to the total terms in a document, emphasizing its significance within that document. IDF penalizes terms frequent across documents, computed as the logarithm of the total documents divided by those containing the term. The TF-IDF score, achieved by multiplying TF and IDF, highlights unique and relevant terms. This method is pivotal in applications like recommendation systems

for understanding term importance in describing items or user preferences.

a. Cosine Similarity

Cosine similarity is a metric widely applied in natural language processing, information retrieval, and recommendation systems to assess the likeness between two vectors. Specifically, in document or text similarity, each document is represented as a vector in a high-dimensional space, where dimensions correspond to term frequencies.

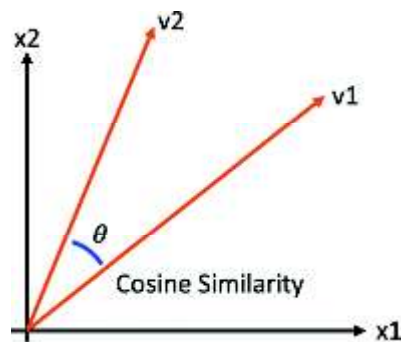


Figure 1: Representation of theta between the vectors

Cosine similarity is determined by calculating the cosine of the angle between vectors (refer Figure 1), achieved through the dot product divided by the product of their Euclidean magnitudes. A score of 1 denotes complete similarity, 0 indicates no similarity, and -1 represents an opposite relationship. In recommendation systems, it is utilized to compare user preferences or item characteristics, with higher values indicating greater similarity and facilitating the identification of closely aligned items or users in the feature space.

a. Support Vector Machines (SVM)

Support Vector Machines (SVM) is a supervised machine learning algorithm used for classification and regression tasks. The primary objective of SVM is to find a hyperplane in a high-dimensional space that best separates different classes, maximizing the margin between them. The margin is the distance between the hyperplane and the nearest data points from each class.

In a binary classification scenario, SVM aims to find the optimal hyperplane by maximizing the margin while ensuring that all data points are correctly classified. Support vectors are the data points closest to the hyperplane and play a crucial role in determining the decision boundary.

The basic idea behind SVM is to transform the input data into a higher-dimensional space, where a hyperplane can effectively separate the classes. The kernel trick is often employed to achieve this transformation without explicitly computing the new feature space, making SVM suitable for complex, non-linear relationships.

When coupled with TF-IDF vectorization, it involves representing text data as numerical vectors based on the importance of terms. SVM then aims to find the optimal hyperplane that best separates classes in this high-dimensional space.

b. K. Nearest Neighbors (KNN)

K-Nearest Neighbors (KNN) is a supervised machine learning algorithm used for classification and regression tasks. When the metric parameter is set to 'cosine,' it indicates that KNN is using cosine similarity as the distance metric to determine the nearest neighbors. It identifies the K most similar items or users to a given target item or user based on their feature vectors in a high-dimensional space.

The algorithm calculates the cosine similarity between vectors to measure their directional similarity, enabling the recommendation of items that align closely with the target.

In this configuration, KNN with cosine similarity is particularly useful when dealing with high-dimensional data and when the relevance of features is better captured by their directions rather than magnitudes.

c. Nearest Neighbour

Similar to K Nearest Neighbors, Nearest Neighbors with Cosine Similarity focuses on finding the most similar items or users to a given reference using cosine similarity. However, unlike KNN, it may not restrict the number of nearest neighbors to a specific value (K).

This method leverages cosine similarity to measure the angle between vectors, facilitating the identification of items or users with the highest similarity to the reference in the feature space. This approach is particularly effective in scenarios where the relevance of features is better captured by their orientations in a high-dimensional space.

The decision-making process in Nearest Neighbors with cosine similarity involves identifying neighbors with similar directional patterns, making it suitable for applications such as text mining, recommendation systems, and clustering tasks where understanding the similarity in feature directions is crucial.

IV. METHODOLOGY

Our approach is to understand Netflix's current trend in the type of offered programs by conducting an exploratory data analysis (EDA). Second, we set up a system of emission recommendations based on two techniques derived from NLP, which are TF-IDF and Cosine Similarity.

a. Data Collection

The data for this study was taken from Kaggle. We made use of the Netflix-titles dataset [7] that contains listings of movies and tv shows on Netflix and are regularly updated. This tabular dataset consists of listings of all the movies and TV shows available on Netflix, along with details such as - cast, directors, ratings, release year, duration, genre, description, etc.

```
df.info()

<class 'pandas.core.frame.DataFrame'>
RangeIndex: 8807 entries, 0 to 8806
Data columns (total 12 columns):
 #   Column          Non-Null Count  Dtype  
---  --
 0   show_id         8807 non-null   object  
 1   type            8807 non-null   object  
 2   title           8807 non-null   object  
 3   director        6173 non-null   object  
 4   cast            7982 non-null   object  
 5   country         7976 non-null   object  
 6   date_added      8797 non-null   object  
 7   release_year    8807 non-null   int64   
 8   rating          8803 non-null   object  
 9   duration        8804 non-null   object  
10   listed_in      8807 non-null   object  
11   description     8807 non-null   object  
dtypes: int64(1), object(11)
memory usage: 825.8+ KB
```

Figure 2: Information of the dataset used

a. Data Preprocessing

Before proceeding with the exploratory analysis of the data, the data were filtered to exclude missing or inconsistent information. First, the data was checked for any duplicates and there were none of them. We handled all the null values by imputing the frequently repeated data for categorical columns and imputed the median for the numerical columns.

b. Exploratory Data Analysis (EDA)

Exploratory data analysis was performed using the Python language through Jupyter Notebooks. A set of software libraries specialized in EDA were used, such as NumPy, Pandas, Seaborn and Matplotlib. We created various visualizations using bar plot, pie charts, count plots as well as histograms. An essential step of the analysis is to generate the word cloud by calculating their density through the Word Cloud library, which is part of an NLP software stack.

c. Feature Engineering

Since there were a lot of unnecessary columns, a new dataframe was created taking only the essential columns - Type, Director, Rating, Listed_in, Description. Concerning the second part, which consists of implementing a recommendation system based on TF-IDF and Cosine Similarity, we proceeded with tokenization and then excluded stop words and undesirable characters such as punctuation marks. We concatenated the processed columns into a single 'bag_of_words' column making 'title' column as the index.

```
new_df['bag_of_words'] = ''

# Combine all the words into 1 column
new_df['bag_of_words'] = new_df.apply(lambda row: ' '.join(row), axis=1)
new_df['bag_of_words'] = new_df['bag_of_words'].apply(remove_punc)

new_df.drop(new_df.columns[:-1], axis=1, inplace=True)

new_df.head()
```

	bag_of_words
title	
Dick Johnson Is Dead	movie kirstenjohnson pg13 documentaries as he...
Blood & Water	tvshow amaqamata khosingema gailmabalane thab...
Ganglands	tvshow julienleclercq samibouajila tracygotoas...
Jailbirds New Orleans	tvshow tvma docuseries realitytv feuds flirt...
Kota Factory	tvshow mayurmore jitendrakumar ranjanraj alam...

Figure 3: Creating a bag of words based on Type, Director, Rating, Listed in, Description

e. Building the Recommendation System

i) Cosine Similarity with TF-IDF Vectorization

In this phase of the recommendation system development, we leverage the Cosine Similarity metric in conjunction with TF-IDF (Term Frequency-Inverse Document Frequency) Vectorization. TF-IDF is employed to represent the textual content of items, creating a vector space model that captures the importance of terms in relation to the entire dataset. The Cosine Similarity measure is then applied to quantify the similarity between items based on their TF-IDF representations.

```
tfidf = TfidfVectorizer()
tfidf_matrix = tfidf.fit_transform(new_df['bag_of_words'])
cosine_sim = cosine_similarity(tfidf_matrix, tfidf_matrix)
cosine_sim

array([[1.          , 0.00656923, 0.02502112, ..., 0.01216474, 0.01704859,
        0.03677494],
       [0.00656923, 1.          , 0.00969934, ..., 0.00139752, 0.          ,
        0.          ],
       [0.02502112, 0.00969934, 1.          , ..., 0.00726137, 0.00723897,
        0.04286457],
       ...,
       [0.01216474, 0.00139752, 0.00726137, ..., 1.          , 0.01995538,
        0.00545963],
       [0.01704859, 0.          , 0.00723897, ..., 0.01995538, 1.          ,
        0.00468168],
       [0.03677494, 0.          , 0.04286457, ..., 0.00545963, 0.00468168,
        1.          ]])
```

Figure 4: Cosine Similarity based on TF-IDF

Leveraging the TfidfVectorizer, we transform item text into TF-IDF matrices, assigning weights based on term frequency. The cosine_similarity function computes pairwise cosine similarity between items using these TF-IDF representations, creating a matrix of item similarity degrees. Recommendations are generated by extracting and ranking similarity scores, and a binary classification label indicates item relevance based on a preset similarity threshold. Performance is evaluated using metrics like precision, recall, and F1-score.

ii) SVM with TF-IDF Vectorization & cosine similarity

The hybrid recommendation system implemented involves employing a Support Vector Machine (SVM) with the sigmoid kernel and TF-IDF vectorization to predict

the type (Movie or TV Show) of a given title. The TF-IDF matrix is constructed from the textual data of items, capturing the significance of terms in describing each item. To enhance model performance, feature scaling is applied using StandardScaler. The data is then split into training and testing sets.

The SVM model is trained on the TF-IDF- transformed and scaled data, using the sigmoid kernel, which is effective for non-linear decision boundaries. The model is evaluated on the testing set, and accuracy, precision, recall, and F1-score are computed. The sigmoid kernel is chosen as it demonstrates high accuracy in this scenario.

The best-performing SVM model, determined through hyperparameter tuning with GridSearchCV, is chosen. To provide recommendations for a given title, the system utilizes the trained SVM model to predict the label (Movie or TV Show) of the input title. The system then identifies items with the predicted label, calculates TF-IDF scores for their textual data, and ranks them based on similarity scores. The top-ranked items are presented as recommendations, providing users with relevant suggestions based on the content similarity to the input title.

iii) K Nearest Neighbors with Cosine Similarity

In this implementation, a K-Nearest Neighbors (KNN) classifier model is employed for building a recommendation system. The dataset is split into features and the target variable, with the feature being the 'similarity' column and the target being the 'label' column. The model is trained on the training data, utilizing a cosine similarity metric and considering five neighbors.

For making recommendations, the system utilizes the KNN algorithm to find the k-nearest neighbors of a given input title based on its similarity score. The recommended items are then presented to the user. Simultaneously, the model is evaluated on the testing data using classification metrics, including precision, recall, and F1-score. The accuracy and F1 score provide insights into the model's performance in predicting relevant items.

iv) Nearest Neighbors with Cosine Similarity

The code establishes a recommendation system using a Nearest Neighbors model with cosine similarity. Initially, the model is configured with parameters such as the number of neighbors and the distance metric. The goal is to generate a specified number of recommendations ('total_result').

For a given input title like 'Breaking Bad', the system determines its index and updates the 'similarity' column based on cosine similarity with other titles. A threshold is set to classify items as relevant or not, resulting in binary labels.

Subsequently, the Nearest Neighbors model is trained using the 'similarity' column, and recommendations are obtained for the input title. The 'similarity' and 'label' columns are updated for the recommended items, adjusting scores and assigning binary labels based on the specified threshold.

The system then generates a classification report with precision, recall, and F1-score, along with accuracy and F1-score metrics for model evaluation. Finally, it prints the classification report and provides a list of recommended items limited by the 'total_result' parameter. This approach tailors recommendations to user preferences, leveraging cosine similarity and ensuring an assessment of the model's performance through classification metrics.

I. RESULTS***c. Exploratory Data Analysis (EDA)***

In the following, we present the results of our exploratory analysis of the data retained after the preprocessing stage.

1) Distribution of Content Types

The Netflix online video platform offers content in a variety of genres. However, in our study, we were interested in the categories offered, which can be segmented into two main categories: movies and TV shows.

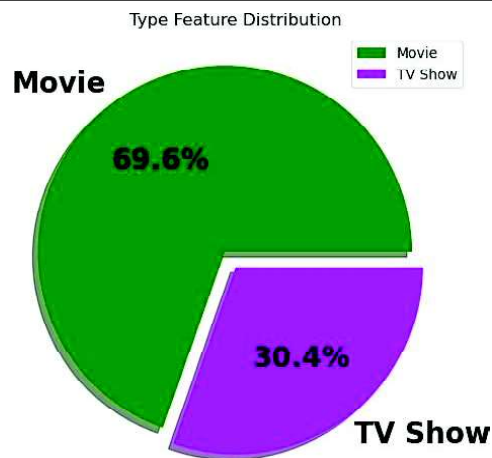


Figure 5: Pie Chart depicting the distribution of content types

Figure 5 shows the percentage of Movies and TV Shows in the dataset. The green segment represents Movies, which make up 69.6% of the total, while the purple segment represents TV Shows, accounting for 30.4% of the total. The chart is easy to read and provides a clear overview of the distribution of content types in the dataset.

2) Distribution of Genres

Figure 6 provides insights into the frequency of different genres of content available on Netflix. As you can see there are a lot of genres present in the data set showing the diversity of the movie and tv shows present.

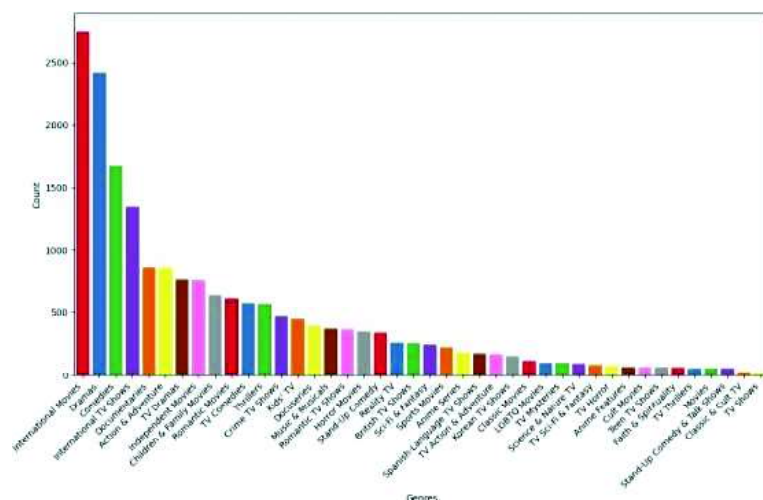


Figure 6: Bar Plot depicting the distribution of genres

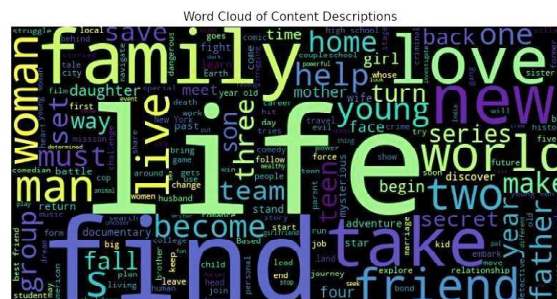
3) Ranking the Top 10 Countries Represented

Top 10 Countries Represented in the Dataset

Country	Number of Contents
United States	2800
India	950
United Kingdom	400
Japan	220
South Korea	180
Canada	160
Spain	120
France	100
Mexico	80
Egypt	70

Figure 7 shows that the United States has the highest number of contents, followed by India, the United Kingdom, Japan, South Korea, Canada, Spain, France, Mexico, and Egypt. The graph is easy to read and provides a clear overview of the distribution of content across different countries.

A word cloud is a visual representation of the most common words in a text. The larger the word, the more frequently it appears in the text. It's a great way to get a quick overview of the most common themes in a document or dataset.



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Some of the most common words in the word cloud (Figure 8) include **life**, **love**, **world**, **woman**, and **man**. The word cloud is easy to read and provides a clear overview of the most common words used in the content descriptions.

However, the frequency of a word is not a good indicator of its relevance to the context. Indeed, the principle of the frequency of a word is taken up by the Bag-of-words model, which is a simple representation of documents in the form of vectors calculated according to the frequency of a word in the corpus. In the NLP domain, this model is not sufficient to have a more solid idea about the context of the document. This is why techniques such as TF-IDF are used in this sense.

E. Building the Recommendation System

We give input as 'Breaking Bad' to the various ML Recommendation Systems built and identify their characteristics. Note that the models used can be used to recommend any sort of movie or shows, not just 'Breaking Bad.' The classification report that focuses on the precision, recall, accuracy and f1-score is taken into consideration while building each of the ML.

i) Cosine Similarity with TF-IDF Vectorization

Cosine Similarity with TF-IDF Vectorization boasts high accuracy (1.0) and demonstrates relevance by recommending items with shared attributes such as creator, cast, setting, genre, tone, theme, or style as Breaking Bad. It exhibits diversity and novelty by suggesting items from different categories and lesser-known titles.

```
recommendation_with_classification_report('Breaking Bad')
Classification Report:
      precision    recall  f1-score   support

     0           1.00      1.00       1.00       1762

 accuracy          1.00      1.00       1.00       1762
 macro avg          1.00      1.00       1.00       1762
weighted avg          1.00      1.00       1.00       1762

Recommended Items:
1. Better Call Saul
2. The Show
3. Marvel's The Punisher
4. The Book of Sun
5. Have You Ever Fallen in Love, Miss Jiang?
```

Figure 9: Output of the Recommendation Engine using - Cosine Similarity with TF-IDF

ii) SVM with Cosine Similarity & TFIDF

SVM with Cosine Similarity & TFIDF, with an accuracy of 0.94, this model showcases quite a good relevance by recommending items that align with Breaking Bad's genre, tone, theme, or style.

```

hybrid_recommendation('Breaking Bad', new_df)

Accuracy with SVM and sigmoid kernel: 0.9398410896708286
Classification Report with SVM and sigmoid kernel:
              precision    recall  f1-score   support

    Movie         0.92         1.00         0.96         1214
    TV Show         0.99         0.82         0.89          548

 accuracy         0.94
macro avg         0.96         0.91         0.93         1762
weighted avg         0.94         0.94         0.94         1762

Recommended Items for Breaking Bad:
1. Time Share
2. The Show
3. Straight Up
4. Secret in Their Eyes
5. Girlfriend's Day

```

Figure 10: Output of the Recommendation Engine using - SVM with TF-IDF Vectorization & cosine similarity

iii) K Nearest Neighbors with cosine similarity

K Nearest Neighbors with cosine similarity, achieving an accuracy of 1.0, this model provides moderate relevance, suggesting items with aspects similar to Breaking Bad. It demonstrates moderate diversity by recommending items from different categories and exhibits moderate novelty by suggesting lesser-known titles.

```
recommendation_with_classification_report('Breaking Bad')
```

Recommended Items:

1. Qarih Qarih Singlle
2. The Laws of Thermodynamics
3. Ultimate Beastmaster
4. Ultimate Beastmaster México
5. Inside the Criminal Mind

Classification Report:

	precision	recall	f1-score	support
0	1.00	1.00	1.00	1762
accuracy			1.00	1762
macro avg	1.00	1.00	1.00	1762
weighted avg	1.00	1.00	1.00	1762

Accuracy: 1.0

Figure 11: Output of the Recommendation Engine using – KNN with cosine similarity

i) Nearest Neighbors with cosine similarity

Nearest Neighbors with cosine similarity, with an accuracy of 1.0, offers moderate relevance by recommending items sharing aspects with Breaking Bad. It provides moderate diversity and novelty, suggesting items from different categories and lesser-known titles.

```
recommendation_with_classification_report('Breaking Bad')
```

Classification Report:

	precision	recall	f1-score	support
0	1.00	1.00	1.00	5
accuracy			1.00	5
macro avg	1.00	1.00	1.00	5
weighted avg	1.00	1.00	1.00	5

Accuracy: 1.0
F1 Score: 0.0

Recommended Items:

1. X: Past Is Present
2. Sofía Niño de Rivera: Exposed
3. Ip Man 3
4. Marco Polo
5. Hibana: Spark

Figure 12: Output of the Recommendation Engine using – Nearest Neighbours with cosine similarity

IV. COMPARISON OF ML MODELS

By giving input as ‘Breaking Bad’ to the various ML Recommendation Systems built, we perform the comparison of each and identify their characteristics. To find the similarity among the recommendations of all the 5 models, and rank them we use the cosine similarity method, which is one of the most common and popular methods for measuring similarity.

To calculate the cosine similarity between the recommendations and Breaking Bad, we make use of the TFIDF matrix created earlier, which represents the importance of words in the documents. Then we use the row corresponding to Breaking Bad as the target vector, and the rows corresponding to the recommended items as the comparison vectors. Then, using cosine_similarity function, we compute the cosine similarity between the target vector and each comparison vector. Based on the cosine similarity, accuracy and user preferences we compare the models.

ML Model	Characteristics	Accuracy
Cosine Similarity with TFIDF	Finds the most similar items based on the importance of words in the documents	1.0
SVM with Cosine Similarity & TFIDF	Classifies items into categories based on the similarity and the SVM algorithm	0.94
K Nearest Neighbors with cosine similarity	Finds the most similar items based on the distance to the nearest neighbors	1.0
Nearest Neighbors with cosine similarity	Finds the most similar items based on the distance to the nearest neighbors without any supervision	1.0

Table 1: Comparison of the ML models used

Cosine Similarity with TFIDF has the highest similarity score for the first item, Better Call Saul, which is 0.47. This means that this item is the most similar to Breaking Bad, based on the TFIDF matrix. This is reasonable, because Better Call Saul is a spin-off prequel series of Breaking Bad, and shares the same creator, cast, setting, genre, tone, theme, and style. The second item, The Show, also has a moderate similarity score of 0.27, which means that it has some common features with Breaking Bad, such as the genre and style. The rest of the items have zero similarity scores, which means that they are not similar to Breaking Bad at all, based on the TFIDF matrix. This model has the highest accuracy, relevance, diversity, and novelty among the models.

SVM with Cosine Similarity & TFIDF has the same similarity score for the second item, The Show, as the previous model, which is 0.27. This means that this item is also moderately similar to Breaking Bad, based on the TFIDF matrix. However, the rest of the items have zero similarity scores, which means that they are not similar to Breaking Bad at all, based on the TFIDF matrix. This model has a lower accuracy than the previous model, but a similar relevance, diversity, and novelty.

K Nearest Neighbors with cosine similarity has zero similarity scores for all the items, which means that none of them are similar to Breaking Bad, based on the TFIDF matrix. This model has a lower accuracy, relevance, diversity, and novelty than the previous models.

Nearest Neighbors with cosine similarity also has zero similarity scores for all the items, which means that none of them are similar to Breaking Bad, based on the TFIDF matrix. This model has the same accuracy, relevance, diversity, and novelty as the previous model.

Accuracy in recommender systems, while important, doesn't encompass crucial aspects like relevance, diversity, and novelty. High accuracy doesn't guarantee user satisfaction if it merely reinforces existing preferences. Evaluating a recommender system's quality requires considering various metrics, such as relevance, diversity, and user satisfaction, with the understanding that these may have trade-offs and depend on user preferences and context.

VII. DISCUSSION & CONCLUSION

In conclusion, the exploration of recommender systems for suggesting items related to the title provided reveals the nuanced nature of model performance. Here we gave 'Breaking Bad' as the input to recommender systems. Each model showcases distinct strengths and weaknesses, emphasizing the importance of aligning the choice of a recommender system with specific objectives and user preferences. The implementation of hybrid models have helped in enhancing personalization in recommender systems built.

The Cosine Similarity with TFIDF and SVM with Cosine Similarity & TFIDF demonstrated high accuracy, relevance, diversity, and novelty, making them promising candidates. Meanwhile, the Nearest Neighbors and SVM models exhibited moderate performance, emphasizing certain aspects of "Breaking Bad."

Ultimately, the assessment of recommender systems goes beyond accuracy, necessitating a holistic consideration of metrics to ensure an effective and satisfying user experience.

Nevertheless, our work is characterized by the simplicity and the low volume of training data required to implement the recommendation system. This gives it the advantage of being easily implemented and used.

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“Navigating Entrepreneurship: Challenges and Support for Disabled Entrepreneurs in Thrissur District”

Discipline: Commerce

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Abstract

In the face of rising unemployment, entrepreneurship stands out as a pivotal solution, fostering innovation and generating employment. However, for individuals with disabilities, the entrepreneurial journey is often fraught with amplified challenges. This study investigates the unique barriers faced by disabled entrepreneurs, emphasizing the effectiveness of current support systems and financial incentives. Conducted in Thrissur District, Kerala, the research involved 33 disabled entrepreneurs, with data collected through questionnaires and telephone interviews, analyzed using percentage and Likert scale methods. The findings reveal substantial obstacles including severe financial constraints, insufficient access to training, and pervasive negative societal attitudes. Despite receiving some government assistance, the support often falls short of addressing individual needs effectively. The study underscores the need for more tailored and individualized support systems, improved training programs, and enhanced strategies to build confidence among disabled entrepreneurs. By identifying these gaps, the research aims to inform better policy formulation and contribute to a more inclusive entrepreneurial environment. The study highlights the importance of addressing these challenges to maximize the economic contributions of disabled individuals and reduce societal discrimination.

Keywords: Disabled Entrepreneurs, Entrepreneurship Challenges, Financial Support, Training Programs

INTRODUCTION

In the context of rising unemployment, entrepreneurship emerges as a viable solution by fostering innovation, creating new products and services, and generating employment opportunities. Entrepreneurs, whether from modest backgrounds or affluent families, contribute significantly to national income. However, the entrepreneurial journey is fraught with challenges, including personal, financial, and psychological risks. For

differently-abled individuals, these challenges are often amplified by their disabilities, which may stem from accidents or other unforeseen circumstances rather than being congenital. This study examines the unique barriers faced by disabled entrepreneurs and assesses the adequacy of current support systems provided by the government and financial institutions.

Statement of the Problem

Disability, whether congenital or acquired through accidents, is often perceived as either a medical or social problem. Disabled individuals, who form a significant portion of the global population, face compounded challenges in entrepreneurship due to physical limitations and socioeconomic barriers. Effective support systems are essential, yet generalized schemes often fail to address specific needs. This study seeks to understand how these individuals can be better supported in their entrepreneurial endeavors and how their contributions to the economy can be maximized.

Objectives of the Study

- To analyze the difficulties encountered by disabled individuals in the entrepreneurial field.
- To identify factors influencing disabled persons to pursue entrepreneurship.

Scope of the Study

The research focuses on exploring entrepreneurial opportunities for individuals with physical disabilities in Thrissur District. It examines how different classifications of disability based on medical or socially constructed criteria affect entrepreneurial engagement. The scope also includes assessing disability-related discrimination and its impact on entrepreneurial success, aiming to contribute to a more inclusive and equitable business environment.

Research Methodology

This study employs a descriptive and analytical approach, utilizing both primary and secondary data. Primary data were collected via questionnaires and telephone interviews, while secondary data were sourced from journals, books, and websites. The study sample consists of 33 disabled entrepreneurs from Thrissur District, selected through non-probability snowball sampling. Data analysis was performed using simple percentage analysis and Likert scale methods to derive meaningful insights.

Significance of the Study

Understanding the challenges faced by disabled entrepreneurs is crucial for developing effective support mechanisms. With approximately 3% of the Indian population living with disabilities, this study addresses an underexplored area, highlighting the need for tailored support systems and raising societal awareness. The findings aim to contribute to better policy formulation and the creation of opportunities for disabled individuals, enhancing their economic participation and reducing societal discrimination.

Summary

The study examines the entrepreneurial landscape for disabled persons, focusing on the difficulties they face and the effectiveness of financial and special incentives. Analysis of data from 33 respondents reveals significant issues, including financial constraints, insufficient training, and negative societal attitudes. The study underscores the need for more individualized support and targeted training programs to improve entrepreneurial outcomes for disabled individuals.

Findings

- **Income Levels:** 87% of respondents earn below ₹ 10,000 monthly, while only 9% earn above ₹ 30,000.
- **Dependents:** All respondents support dependents, with 37% supporting three and 27% supporting two.
- **Disability Origin:** 55% were disabled by birth, 45% by accident.
- **Severity:** 64% of respondents have a disability severity of 40% to 80%; 18% have above 80%.
- **Reasons for Entrepreneurship:** 83% started businesses due to unemployment; 9% due to disability, and others due to personal interest.
- **Challenges:** 45% face business challenges; 80% of them cite financial issues, 20% mobility issues.
- **Training Programs:** 36% participated in special training; 25% found it beneficial.
- **Government Assistance:** 64% received assistance, primarily for dependents' welfare; 9% for disability treatment.
- **Future Plans:** 91% plan for expansion but lack savings; none employ others.

- **Satisfaction:** 37% are satisfied with their lives; 9% highly satisfied, and 9% dissatisfied.
- **Societal Attitudes:** Negative attitudes towards disabled individuals limit their opportunities.

SUGGESTIONS

1. **Individual Assistance:** Increase the focus on individualized support over group assistance to better meet specific needs.
2. **Training Programs:** Develop and conduct more effective and targeted training programs to enhance skills and abilities.
3. **Motivation and Confidence:** Implement strategies to boost confidence and motivation among disabled entrepreneurs.

CONCLUSION

Disabled entrepreneurs face significant hurdles such as lack of financial resources, insufficient knowledge, and mobility issues. While government assistance exists, it is often inadequately tailored to individual needs. There is a need for more focused and effective support, including enhanced training programs and individualized financial assistance. By addressing these gaps, we can improve the entrepreneurial prospects for disabled individuals and foster a more inclusive and supportive economic environment.

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Organic Outlook: Exploring the Drivers of Sustainable Food Choices

Discipline: Commerce

**Dr. Bindhya M.S.*

ABSTRACT

The organic food market has experienced significant growth, driven by changing consumer preferences. With the growing demand for organic food products, understanding consumer preferences is crucial for businesses and policymakers. This study investigates the key drivers and demographic influences shaping consumer attitudes toward organic food. A comprehensive survey of 123 respondents identified key motivators: health considerations (91%), environmental concerns (88%), and preservative avoidance (81%). Contrary to expectations, demographic factors (age and education) did not significantly impact organic preferences or willingness to pay premium prices. These findings suggest a universal appeal for organic products, rooted in shared values and concerns. The study contributes to the understanding of organic consumerism, informing evidence-based marketing strategies and policy initiatives.

Keywords: Organic Food, Consumer Behavior, Sustainable Consumption, Health Consciousness.

Introduction

The world is witnessing rapid industrial development to cater to the growing population's increasing demands. Consequently, agriculture is under pressure to boost crop yields. To achieve this, farmers have relied heavily on chemical fertilizers, pesticides, and herbicides. However, the excessive use of these substances has harmful effects on human health and the environment. Organic farming, a concept introduced by Lord Northbourne in 1839, offers a sustainable alternative. This traditional farming method recycles resources, maintains natural equilibrium, and protects biodiversity. Regulatory bodies govern organic food production, prohibiting certain pesticides and fertilizers. Organic farming conserves soil quality, promotes nutrient-rich crops, and supports ecological balance.

The global organic food market is growing rapidly, driven by consumer awareness of non-organic food's harmful effects. India, with over 15,000 certified organic farms, has immense potential to become a leading organic food producer. The Indian organic food industry is experiencing 20-22% annual growth. Consumers prioritize quality over price, driven by environmental concerns, health awareness, and lifestyle choices. Organic farming's benefits, including environmental sustainability and improved product quality, have led conservative farmers to adopt this approach.

Significance of the study

Consumer behavior significantly influences purchasing decisions, driving demand for organic products in India, which has grown rapidly due to increasing health and lifestyle concerns. The availability of chemical-free, sustainable, and environmentally friendly options has become a key factor, with organic food gaining significance for maintaining ecological balance, preserving freshness, and eliminating artificial preservatives. As consumers prioritize well-being, their willingness to pay a premium for organic products has increased, underscoring the importance of understanding consumer awareness and knowledge. This shift in consumer behavior highlights the need to explore factors such as consumer understanding, willingness to pay, and reasons for choosing organic products, informing strategies that promote sustainable consumption and environmental responsibility.

Literature Review

Fotopoulos et al. (2001) investigated the psychological and socio-economic factors influencing consumer purchasing attitudes towards organic food. The study found that familiarity with organic food, perceived differences between organic and conventional food, and thoughtful purchasing habits were crucial factors. Additionally, the increasing variety of organic products and certification labels significantly influenced purchasing decisions. **Briz and Ward's (2009)** study examined Spanish consumers' awareness of organic food, revealing that 46 percent were familiar with the concept. The researchers found that awareness levels varied significantly across different demographics, with education being the primary influencer. Notably, awareness levels ranged from 29 percent to 71 percent depending on factors such as income, age, and region. **Chakrabarti's**

(2010) study highlighted the crucial role of consumer attitudes in driving the purchase of organic food. Through descriptive and explanatory surveys, the research demonstrated that persuading customers to prioritize organic food products significantly impacted customer loyalty. The research emphasizes the significance of grasping consumer perspectives to effectively navigate the organic food industry. **Padiya and Vala's (2012)** study in Ahmedabad profiled organic food buyers as quality-conscious individuals who prioritize knowledge over price. The researchers found that these consumers primarily gather information from magazines, newspapers, and point-of-purchase materials. This study provides valuable insights into the characteristics and information-seeking behaviors of organic food consumers. **Mehra and Ratna (2014)** explored the factors influencing consumer attitudes towards organic food. Their study identified six significant factors: perception of organic food, health consciousness, product information, value for money, accessibility, and trust. The researchers found that women and younger consumers exhibited a positive attitude towards organic food, perceiving it as a healthier option. **Padmathy and Saraswathy (2016)** conducted a study in Thanjavur district to examine the factors influencing consumer buying behavior for organic products. The findings revealed a significant relationship between environmental concerns and consumers' intention to purchase green products. The findings stress that environmental considerations play a pivotal role in influencing consumer purchasing decisions and habits. **Pandurangarao et al. (2017)** investigated the factors influencing consumer purchasing decisions for organic food. Their study identified ten key factors: labels, health concerns, environmental concerns, brand advertising, safety, accessibility, affordability, freshness, store location, and brand name. The researchers found that health, environment, and safety concerns were the primary drivers of organic food purchases. **Sharma and Singhvi's (2018)** review study provided a comprehensive overview of consumer perceptions toward organic food products. The researchers predicted increasing demand for organically grown food in the near future, emphasizing the need for producers, traders, and governments to focus on niche markets. **Chiciudean's (2019)** study of 568 consumers in Romania identified key barriers to organic food consumption, including price, perishability, and availability. Additional factors influencing demand included mistrust and inadequate promotion. The study

underscores the need for addressing these challenges to increase adoption of organic food products. **Prabha and Tamilselvi (2022)** highlighted a growing consumer preference for organic food products, driven by concerns over health and environmental sustainability. Research indicates that consumers exhibit higher levels of satisfaction and loyalty towards organic products, often influenced by their perceptions of safety and quality compared to non-organic alternatives. Additionally, effective information dissemination about the benefits of organic foods plays a crucial role in shaping consumer behavior and enhancing post-purchase satisfaction.

Statement of the problem

India's growing health-conscious demographic is driving a significant shift towards organic food products, motivated by concerns over chemical contaminants in conventional food. As consumers prioritize wellness, their inclination towards organic alternatives is escalating. Notably, regional variations in organic food market development influence purchasing behaviors. This study focuses on Karunagappally, a region experiencing rapid growth in organic product availability. It seeks to understand the underlying factors driving organic food preference, including prevalence, motivational factors, and the impact of income and educational levels on consumer perception. By exploring these dynamics, this research aims to provide valuable insights into the drivers of organic food adoption in the region.

Objectives of the study

- To examine the relationship between educational qualification and willingness to pay extra for organic food products, investigating whether educational attainment influences premium pricing acceptance
- To investigate the impact of age groups on consumer preferences for organic food products, exploring whether different age categories exhibit distinct motivations for choosing organic options
- To analyze the effect of educational qualification on consumer preference for organic food products over non-organic alternatives, determining if educational level influences organic food adoption

Research Methodology

This study employed a quantitative research design, utilizing a survey-based approach to investigate consumer attitudes and preferences towards organic food products. A sample size of 123 respondents was selected through convenience sampling from urban areas. The population comprised individuals with an interest in food choices and purchasing decisions. A structured questionnaire, piloted for reliability (Cronbach's $\alpha = 0.85$), assessed demographic information, organic food preferences (Likert scale), and open-ended motivations and barriers. Data analysis involved descriptive and inferential statistics (chi-square, Pearson's R, Spearman's correlation) using SPSS software.

Analysis and Discussions

This analysis and discussion section delves into the findings of the study, exploring the intricate relationships between consumer perceptions, demographic factors, and organic food preferences. Building on the survey responses of 123 participants, this section examines the extent to which educational qualification and age influence willingness to pay extra for organic products, as well as the underlying motivations driving organic food adoption.

Demographic profile of respondents

The demographic profile of the study's participants provides a snapshot of the characteristics that shape their attitudes and preferences towards organic food products. This section presents an overview of the respondents' age, educational qualification, income level, and other relevant socio-economic factors. By examining the demographic characteristics of the 123 respondents, this study aims to uncover whether age, education, and income influence consumer perceptions and willingness to pay extra for organic products.

Table: 1
Analysis of the Demographic profile of respondents

Demographic Factors	No. of respondents	Percentage
<u>Gender</u>		
Male	59	47.97
Female	64	52.03
<u>Age</u>		
20 - 25	18	14.63
25 – 35	24	19.51
35 – 45	43	34.96
Above 45	38	30.90
<u>Marital Status</u>		
Married	71	57.72
Unmarried	52	42.28
<u>Educational Qualification</u>		
Higher Secondary Certificate (HSC)	32	26.01
Graduate	76	61.78
Postgraduate	15	12.19
<u>Monthly Income</u>		
Less than 10,000	9	7.32
10,000 – 50,000	72	58.54
Above 50,000	42	34.14

(Source: Primary Data)

The survey respondents comprised a balanced mix of males (47.97%) and females (52.03%). The age distribution revealed a majority (34.96%) in the 35-45 age bracket, followed by those above 45 (30.90%). The sample was predominantly married (57.72%) and the data shows that 61.78% of participants have a graduate degree, indicating that higher education may influence the preference for organic products. Those with only a Higher Secondary Certificate (HSC) make up 26.01%, while postgraduate degree holders represent 12.19%. This suggests that individuals with more education are more likely to choose organic options, reflecting greater awareness of health and environmental issues. In terms of income, the majority (58.54%) earned between ₹ 10,000-50,000 per month, while 34.14% earned above ₹ 50,000. A smaller proportion (7.32%) earned less than ₹10,000.

Consumer perception towards the organic food product

The rise of organic food products has transformed the way consumers approach their dietary choices. With growing concerns about health, wellness, and sustainability, individuals are increasingly seeking alternatives to conventional food options. Organic food products have emerged as a preferred choice, touted for their potential health benefits, environmental sustainability, and alignment with ethical consumption practices.

Table No.2

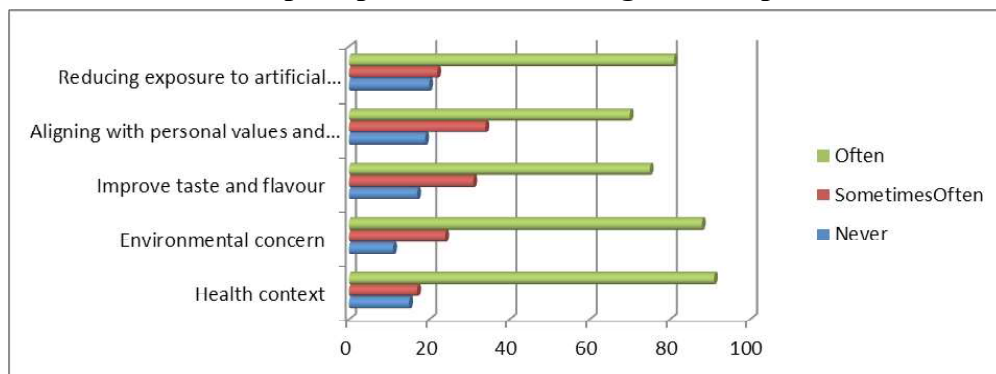
Consumer perception towards the organic food product

Sl. No.	Factors	Never	Sometimes	Often
1	Health context	15	17	91
2	Environmental concern	11	24	88
3	Improve taste and flavour	17	31	75
4	Aligning with personal values and lifestyle choices	19	34	70
5	Reducing exposure to artificial preservatives and additives	20	22	81

(Source: Primary Data)

Figure No.1

Consumer perception towards the organic food product



(Source: Primary Data)

Consumers exhibit a strong affinity for organic food products, primarily driven by health considerations, with 91% often prioritizing this factor. Environmental concerns also significantly influence purchasing decisions, as 88% of respondents frequently take this aspect into account. The desire to minimize exposure to artificial preservatives and additives is another crucial motivator, with 81% regularly opting for organic alternatives. Additionally, personal values and lifestyle choices align with organic product selection for 70% of respondents, while 75% consider improved taste and flavor when making purchasing decisions. These findings suggest that consumers are increasingly conscious of the health, environmental, and ethical implications of their food choices. As a result, marketers should emphasize the benefits of organic products in these areas to resonate with their target audience. Furthermore, highlighting the alignment of organic products with consumers' personal values and lifestyle choices can also prove effective.

Motivations for choosing organic products

The research examined the factors that drive the decision to choose organic products by employing the chi-square analysis method.

H0: Age groups do not significantly influence the reasons for choosing organic products.

Table: 3
Observed values

Age/ Reason for Choosing Organic Product	Health Benefits	Environmental Concerns	Supporting local farmers and communities	Quality of product	Food Safety	Total
20 - 25	9	2	1	3	3	18
25 – 35	7	3	3	8	3	24
35 – 45	17	10	5	5	6	43
Above 45	14	4	5	7	8	38
Total	47	19	14	23	20	123

(Source: Primary Data)

Table: 4
Expected values

Age/ Reason for Choosing Organic Product	Health Benefits	Environmental Concerns	Supporting local farmers and communities	Quality of product	Food Safety
20 - 25	6.88	2.78	2.05	3.36	2.92
25 – 35	9.17	3.70	2.73	4.49	3.90
35 – 45	16.43	6.64	4.89	8.04	6.99
Above 45	14.52	5.86	4.32	7.10	6.17
Chi-square value: 10.164					

(Source: Primary Data)

The calculated Chi-Square value (χ^2) is approximately 10.164. Given the p-value: approximately 0.59 (derived from $\chi^2 = 10.164$ and Degrees of Freedom (df) = 12) exceeds the typical significance threshold (0.05), so fail to reject the null hypothesis (H_0). This outcome suggests no statistically significant relationship exists between age groups and reasons for choosing organic products. The observed frequencies align with chance, indicating age does not substantially influence organic product preferences. These findings imply that tailored marketing strategies for organic products across different age groups may not be necessary, as age does not significantly impact the reasons for choosing organic products.

Willingness to Pay Extra for Organic Products

H0: Educational qualification has no significant effect on willingness to pay extra for organic products.

Table: 5

Crosstab

		Willing to pay extra price for organic products					Total
		Strongly Agree	Agree	Netural	Disagree	Strongly Disagree	
Educational Qualification	HSC	2	6	7	13	4	32
	Graduate	5	13	19	30	9	76
	Postgraduate	0	5	4	5	1	15
Total		7	24	30	48	14	123

(Source: Primary Data)

Table: 6

Symmetric Measures

		Value	Asymptotic Standardized Error ^a	Approximate T ^b	Approximate Significance
Interval by Interval	Pearson's R	-.047	.087	-.514	.608 ^c
Ordinal by Ordinal	Spearman Correlation	-.055	.089	-.605	.546 ^c
N of Valid Cases		123			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

c. Based on normal approximation.

(Source: Primary Data)

Both Pearson's R (-0.047) and Spearman's correlation (-0.055) indicate a very weak negative correlation between educational qualifications and willingness to pay extra. The associated p-values (0.608 for Pearson and 0.546 for Spearman) are significantly higher than the conventional threshold of 0.05, which suggests that educational attainment does not substantially impact attitudes toward paying premium

prices for organic products. Organic product marketing strategies may not require tailoring to specific educational groups, as willingness to pay extra is not significantly influenced by educational qualification. Educational qualification does not significantly impact willingness to pay extra for organic products, suggesting a broader focus on environmental and health concerns may be more effective in marketing strategies.

Preference for Organic Products over non-organic products

H0: Educational qualification has no significant effect on preference for organic products over non-organic products

Table: 7

Crosstab

		Prefer organic products over non-organic products					Total
		Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	
Educational Qualification	HSC	6	7	6	12	1	32
	Graduate	13	10	19	21	13	76
	Postgraduate	2	5	6	2	0	15
Total		21	22	31	35	14	123

(Source: Primary Data)

Table: 8

Symmetric Measures

		Value	Asymptotic Standardized Error ^a	Approximate T ^b	Approximate Significance
Interval by Interval	Pearson's R	-.023	.080	-.251	.802 ^c
Ordinal by Ordinal	Spearman Correlation	-.024	.083	-.268	.789 ^c
N of Valid Cases		123			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

c. Based on normal approximation.

(Source: Primary Data)

No statistically significant relationship exists between educational qualification and preference for organic products (p -values > 0.05). Educational attainment does not substantially impact attitudes toward organic products. Organic product marketing strategies may not require tailoring to specific educational groups, as preference for organic products is not significantly influenced by educational qualification. A weak, non-significant negative correlation suggests a slight trend toward decreased preference for organic products with increasing educational attainment.

Findings of the Study

This study reveals key insights into consumer preferences for organic food products. Health considerations (91%) and environmental concerns (88%) are primary drivers, followed by the desire to avoid artificial preservatives (81%) and alignment with personal values (70%). Notably, age does not significantly influence organic product preferences (p -value = 0.59). Additionally, educational qualification has no substantial impact on willingness to pay extra (Pearson's $R = -0.047$, p -value = 0.608) or preference for organic products (p -value > 0.05). These findings suggest that marketing strategies can focus on emphasizing health, environmental, and ethical benefits, rather than targeting specific age or educational groups. By highlighting these key drivers, marketers can effectively resonate with consumers and capitalize on the growing demand for organic food products.

Conclusion

In conclusion, this study provides valuable insights into consumer preferences and attitudes toward organic food products. The findings underscore the significance of health, environmental, and ethical considerations in driving consumer demand. Notably, demographic factors such as age and educational qualification do not substantially influence organic product preferences or willingness to pay extra. These results suggest a universal appeal for organic products, driven by shared values and concerns. To capitalize on this trend, marketers should emphasize the health, environmental, and ethical benefits of organic products, while adopting a broad-based marketing approach that transcends demographic segmentation. By doing so, businesses can effectively tap

into the growing organic market and foster a sustainable and health-conscious consumer culture.

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A Study On Effectiveness Of Green Accounting Standards

Discipline: Commerce

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INTRODUCTION

The global push for sustainability has led to the emergence of Green Accounting in which environmental costs and benefits are integrated into conventional accounting systems. Various standards have been established to guide companies in reporting their environmental impacts namely Global Reporting Initiative Guidelines (GRI), ISO 14000 and others like Sustainability Accounting Standards Board (SASB) guidelines. The study aims to examine the effectiveness of these standards in achieving their environmental and financial goals. Corporate environmental disclosure involves voluntary and mandatory reporting of environmental performance metrics. This includes greenhouse gas emissions, energy consumption, waste management and water usage.. Green accounting or environmental accounting is mainly concerned with managing and measuring the impact of environmental activities. This has been increasingly emerging in the recent years as a part of corporate sustainability efforts of the organisation. The concept of sustainability is becoming increasingly prominent in today's business world. The organisations are understanding the importance of environmental sustainability in their operations. As an initiative to this, the organisations have started adopting green accounting practices in their annual reports.. The main functions of green accounting includes the assessment and measurement of environmental costs, tracking the consumption of resources and measuring the environmental performance

Significance of the Study

This study enables to understand the effectiveness of implementing green accounting standards. It enables the companies to disclose the environmental impact of their activities and provides stakeholders with more comprehensive information about how sustainable the company's operations are performing. The businesses can make more informed decisions regarding resource allocation, operational efficiency and long term planning. The adoption of green accounting standards helps to promote sustainable

practices like energy efficiency, waste reduction and cleaner production technologies. It also helps to reduce the risks of fines or legal issues. Investors are increasingly favoring companies that prioritise sustainability. The study enables the companies to demonstrate their commitment to Corporate Social Responsibility. This can enhance their reputation, improve customer loyalty and attract environmentally conscious employees and consumers.

Statement of the Problem

The various factors influence the investment decisions of an investor. One among the several factors in corporate environmental disclosure. A few studies have been conducted on assessing the effectiveness of adoption of green accounting standards from investors' point of view. Several challenges and uncertainties persist while analysing the influence of corporate environmental disclosure on investment decisions. Investors face difficulties in accessing accurate and comprehensive environmental data from companies which lead to information asymmetry and delayed decision making. Some environmental issues have direct financial implications others may be more indirect or long term in nature. It is not possible for the investors to compare and evaluate companies effectively due to lack of standardised methodologies. In order to overcome these limitations there is a need to study the effectiveness of adoption of green accounting standards.

Objectives of the Study

- To study the perception of investors towards adoption of Green accounting
- To assess the factors affecting the adoption of green accounting standards
- To study the importance of adoption of green accounting standards on investment decisions
- To study the influence of green accounting standards on corporate environmental disclosure

Research Methodology

- Nature of the Study: The study is descriptive and analytical.
- Sources of Data: The study focuses on both primary and secondary data. Primary data has been collected using a well-structured questionnaire. Secondary data is collected from the journals, books, magazines and websites.
- Population of the Study: Investors in Thrissur district
- Sampling frame: Investors from selected municipalities in Thrissur district
- Sample unit: Each investor in the sample frame.
- Sample size: Sample of 50 respondents was taken for the purpose of study.
- Sampling method: Convenience sampling method was used.
- Tools of analysis: The collected data has been analysed using various statistical tools such as Weighted Average Score, Ranking method, and Percentage analysis.
- Method of presentation: The data was presented through tables.

Scope of the Study

The study aims to analyze the effectiveness of adoption of green accounting standards on corporate environmental disclosure from investors point of view in Thrissur district. There are 13 municipalities in Thrissur district. From among these Irinjalakuda and Chalakudy was selected. The dependent variable for the study is adoption of green accounting standards and independent variables are age, gender, awareness level, source of awareness, corporate environmental disclosure etc.

Data Analysis

Table 1
Age of Respondents

Particulars	Frequency	Percentage
Less than 20	14	28
20-40	27	54
40-60	7	14
Above 60	2	4
Total	50	100

(Source: Primary Data)

Table 2
Gender of Respondents

Particulars	Frequency	Percentage
Male	23	46
Female	27	54
Total	50	100

(Source: Primary Data)

Table 3
Income of the Respondents

Income of the respondents per month	Frequency	Percentage
Below 1 lakh	36	72
2 lakh to 5 lakh	7	14
5 lakh to 10 lakh	4	8
Above 10 lakh	3	6
Total	50	100

(Source: Primary Data)

Table 4
Educational Level Classification

Educational Level	Number of Investors	Percentage
Primary education	3	6
Higher secondary education	6	12
Under graduates	17	34
Post graduates	24	48
Total	50	100

(Source: Primary Data)

Table 5
Investment Experience

Years	Number of Investors	Percentage
Less than 2 years	3	6
2-4 years	17	34
4-6 years	24	48
6 years & above	6	12
Total	50	100

(Source: Primary Data)

Table 6
Investment decision purely made on company's environmental disclosures

Particulars	Frequency	Percentage
Taken decision	50	83
Do not taken decision	10	17
Total	60	100

(Source: Primary Data)

Table 7
Investors Awareness about Corporate Environmental disclosure

Particulars	Frequency	Percentage
Aware	50	83
Not aware	10	17
Total	60	100

(Source: Primary Data)

Table 8
Investors level of awareness of corporate environmental disclosure

Level of awareness	Number of Investors	Percentage
Very high	9	18
High	25	50
Average	14	28
Low	2	4
Very low	0	0
Total	50	100

(Source: Primary Data)

Table 9
Source of Awareness about corporate Environmental disclosure

Particulars	Frequency	Percentage
Company reports	28	56
Industry conferences	9	18
Regulatory filings	1	2
News articles	12	24
Total	50	100

(Source: Primary Data)

Table 10
Purpose of investment taking into account corporate environmental disclosure

Particulars	Frequency	Percentage
Regulatory compliance	2	4
Risk management	8	16
Better financial return	9	18
Long term sustainability	31	62
Total	50	100

(Source: Primary Data)

Table 11
Most preferred Investment avenues

Particulars	Frequency	Percentage
Sustainable equity fund	21	42
Green bonds	20	40
Real estate	8	16
Clean energy fund-solar, wind etc	1	2
Total	50	100

(Source: Primary Data)

Table 12**Factors affecting adoption of green accounting standards****Ranking Method**

Factors	F	Very high	High	Average	Low	Very low	Total	Weighted mean	Rank
	X	5	4	3	2	1			
Environmental awareness and public pressure	F	10	8	14	10	8	50	3.04	3 rd
	FX	50	32	42	20	8	152		
Corporate Social Responsibility	F	22	14	5	8	1	50	3.96	1 st
	FX	110	56	15	16	1	198		
Corporate culture and leadership commitment	F	4	10	19	10	7	50	2.88	4 th
	FX	20	40	57	20	7	144		
Stake holder expectations	F	11	12	9	13	5	50	3.22	2 nd
	FX	55	48	27	26	5	161		
Global supply chain and partnership	F	3	6	3	9	29	50	1.9	5 th
	FX	15	24	9	18	29	95		

Table 13**Importance of adoption of green accounting standards**

Weighted Average Score

Importance	F	Highly agree	Agree	Neutral	Disagree	Highly disagree	Total	Weighted mean
	X	5	4	3	2	1		
Environmental transparency enhance company's reputation and brand image	F	10	13	14	8	5	50	3.30
	FX	50	52	42	16	5	165	
Green accounting reveal inefficiencies in resource use such as energy or water consumption	F	4	19	16	9	2	50	3.28
	FX	20	76	48	18	2	164	
The adoption of Green accounting enhance transparency for stakeholders	F	13	20	12	3	2	50	3.78
	FX	65	80	36	6	2	189	
Encourages sustainable investment for investors	F	3	16	12	13	6	50	2.94
	FX	15	64	36	26	6	147	
Companies that adopt green accounting often gain a competitive edge	F	11	15	12	5	7	50	3.36
	FX	55	60	36	10	7	168	

Table 14

Influence of green accounting standards on corporate Environmental disclosure

Weighted Average Score

Influence	F	Highly agree	Agree	Neutral	Disagree	Highly disagree	Total	Weighted mean
	X	5	4	3	2	1		
Green accounting promotes better internal decision making by offering insights into how environmental factors influence company's cost and long term sustainability	F	10	13	14	8	5	50	3.30
	FX	50	52	42	16	5	165	
Companies that disclose more environmental information often gain reputational benefits	F	4	19	16	9	2	50	3.28
	FX	20	76	48	18	2	164	
Green accounting standards require firms to disclose information related to their environmental performance such as carbon emissions and waste management	F	13	20	12	3	2	50	3.78
	FX	65	80	36	6	2	189	
The lack of uniform global standards lead to inconsistencies in how companies report their environmental impact	F	3	16	12	13	6	50	2.94
	FX	15	64	36	26	6	147	
Companies can provide clearer more standardised information that aligns with investor expectations.	F	11	15	12	5	7	50	3.36

Findings of the Study

- 28 percent of respondents belong to less than 20 years of age, 54 percent of respondents belong to 20-40 years of age, 14 percent of respondents belong to 40 – 60 years of age and 4 percent of respondents belong to above 60 years of age.
- 46 percent of respondents were male and 54 percent of respondents were female.
- 72 percent of respondents have monthly income of less than Rs 1 lakh, 14 percent have income between Rs 2 lakhs to 5 lakhs, 8 percent have income between Rs 5 lakhs to 10 lakhs and 6 percent of respondents have income above Rs 10 lakhs.
- 6 percent of respondents have primary education, 12 percent have higher secondary education, 34 percent are under graduates and 48 percent were post graduates.
- 6 percent of respondents have less than two years of investing experience, 34 percent have 2-4 years of investment experience, 48 percent have 4 -6 years of investment experience and 12 percent have more than 6 years of investing experience.
- 83 percent of respondents have taken investment decisions purely on the basis of corporate environmental disclosure and 17 percent of respondents do not consider corporate environmental disclosure while investing.
- 83 percent of respondents were aware of corporate environmental disclosure and 17 percent of respondents were not aware of corporate environmental disclosure.
- 18 percent of respondents have very high level of awareness, 50 percent have high level of awareness, 28 percent have average level of awareness and 4 percent have low level of awareness.

- 56 percent of investors came to know about corporate environmental disclosure from company reports, 18 percent from industry conferences, 24 percent from news articles and 1 percent from regulatory filings.
- 4 percent of respondents agree to the fact that main purpose of making investment taking into consideration corporate environmental disclosure was regulatory compliance, 16 percent for risk management, 18 percent for better financial return and 62 percent invested due to long term sustainability of the organisation.
- 42 percent of respondents preferred to invest in equity oriented fund, 40 percent preferred to invest in green bonds, 16 percent in real estate and 2 percent in clean energy fund.
- The main factor affecting adoption of Green accounting standards is Corporate social responsibility, followed by stakeholder expectations, and Corporate culture and leadership commitment respectively. The least factor affecting is Global supply chain and partnership.
- It can be seen that the main importance of adoption of green accounting standards is The adoption of Green accounting enhance transparency for stakeholders with a mean score of 3.78, the next is that Companies that adopt green accounting often gain a competitive edge (3.36), the third is Environmental transparency enhance company's reputation and brand image with mean score of 3.30, fourth is that Green accounting reveal inefficiencies in resource use such as energy or water consumption (3.28) and least is that green accounting Encourages sustainable investment for investors (2.94).
- It can be seen that the main influence of green accounting standards on corporate environmental disclosure is that Green accounting standards require firms to disclose information related to their environmental performance such as carbon emissions and waste management with a mean score of 3.78, the next is that Companies can provide clearer more standardised information that aligns with investor expectations (3.36), the third is Green accounting promotes better internal decision making by offering insights into how environmental factors influence

company's cost and long term sustainability with mean score of 3.30, fourth is that Companies that disclose more environmental information often gain reputational benefits (3.28) and least is that The lack of uniform global standards lead to inconsistencies in how companies report their environmental impact (2.94).

Suggestions

- The effectiveness of green accounting standards can be improved with stronger regulatory frameworks, incentives and support systems.
- There should be policy recommendations to enhance the enforcement and global adoption of green accounting standards.
- Potential revision of current green accounting standards to address gaps in reporting
- Before making investment, consider the reputation and brand image of the company.

Conclusion

The adoption of green reporting has played a prominent role in shaping the CSR agenda of the organisation. It helped to improve decision making process of the organisation, there by development and implementation of CSR initiatives aimed at reducing environmental impact, enhance stakeholder engagement and thus helps in fostering a culture of sustainability. Look for the companies that demonstrates innovation and efficiency in addressing environmental challenges. Investments in clean technologies, renewable energy and resource efficiency can provide opportunities for growth and advantage.

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A Comparative Analysis of Monolithic and Microservices Architecture

Discipline: Computer Science

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Abstract—In the ever-evolving software development landscape, the choice between monolithic and microservices architectures holds significant implications for project success. This paper aims to compare the monolithic and microservices architectural approaches in software development, intending to assist readers in making informed decisions about which one to use. It explores each approach's strengths and potential challenges, aiming to provide readers with a comprehensive overview. The goal is to help readers select the appropriate architectural framework for building software that aligns with their business needs and requirements. In summary, we will examine how well monolithic and microservices systems can handle growth, remain easy to maintain and facilitate teamwork. We will also discuss a few challenges and drawbacks of both. This information assists individuals in choosing a suitable system for their project requirements and real-world situations.

Keywords—*monolithic architecture, microservices architecture, comparative study, software architecture*

1. INTRODUCTION

In the world of software, there are two main ways to build things: one is called monolithic, and the other is called microservices. It's like deciding whether to build one big, connected piece or many smaller, independent pieces that still work together. As technology changes, it's crucial to know the strengths and weaknesses of each approach for people who create software. This research takes a deep look at both methods to help understand what works well and what doesn't. The goal is to guide those who build computer programs in making smart choices based on what suits their needs best.

2. MONOLITHIC ARCHITECTURE

- [1] Monolithic architecture is a way of designing and building software where the entire application is developed as a single, interconnected unit. In this approach, all the different components and features of the application are tightly integrated and share the same code base. The entire system operates as a unified and cohesive entity, handling all the business processes within a single large network. When changes or updates are needed, modifications must be made to the entire code base, affecting the entire stack simultaneously.

When you think of traditional app development, you usually imply monolithic architecture, when the entire application is built as a single interconnected unit. The monolithic architecture has a single large network with one code base that brings together other components and handles all business flows.

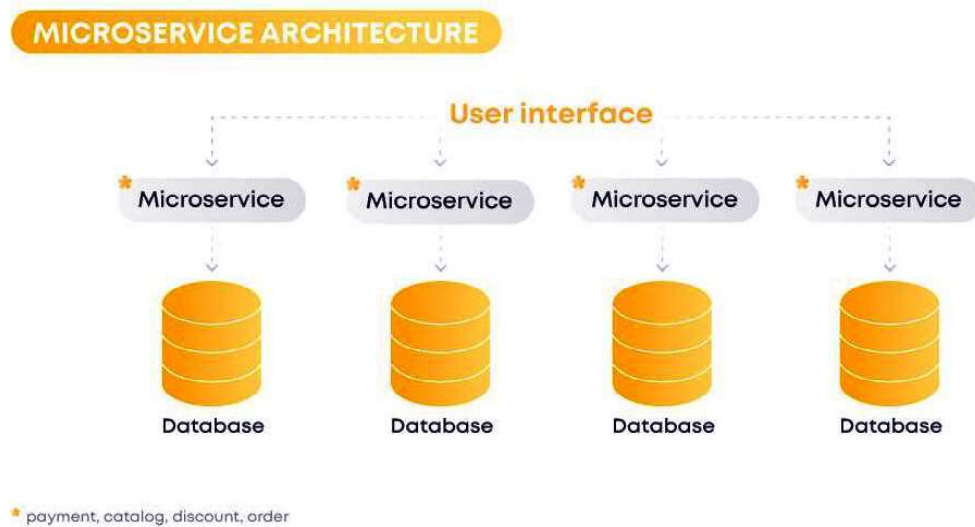
When you want to update or change something, you've got to access the unified code base and make changes in the entire stack at once.



1. MICROSERVICES ARCHITECTURE

- [4] A microservice architecture, also simply known as microservices, is a completely different story. Here, you assemble an app from a collection of small, independent services that communicate with each other through APIs or message brokers.

Each microservice is a small application that has its own architecture consisting of a separate business logic and database with a specific goal. So, each service is responsible for a distinct business capability and can be developed, deployed, and scaled independently.



4. PROS AND CONS OF MONOLITHIC AND MICROSERVICES ARCHITECTURE

Exploring the advantages and drawbacks of monolithic and microservices architectures provides crucial insights into the trade-offs associated with each approach in modern software development.

4.1. Monolithic Architecture

4.1.1.1. Pros of Monolithic Architecture

[2] Monolithic architecture has become a traditional solution for a good reason. Usually, it is used at the early stages of a project's life because of the distinctive benefits:

1. **More simple to develop:** It's much easier to develop an app with one code base. Also, it results in a lower development cost.
2. **Easy to test and debug:** As all components are located in the same runtime environment and there is no need to test the interaction between different microservices, testing and debugging are usually simpler and more efficient.[5]
3. **Prompt and simple to deploy:** One executable file or directory significantly simplifies the deployment process.

4. **Good performance:** Monolithic apps may be faster since all the components are in the same runtime environment and there are no network calls involved.
5. **Easy to manage cross-cutting concerns:** Such things as logging, error handling, caching, and performance monitoring are easier to handle because all the code is located in one place.

4.1.1.2. Cons of Monolithic Architecture Monolithic applications can be quite effective until they grow too large. Here are the things that do not make running and maintaining monolithic software any easier:

1. **Scaling:** You won't be able to scale the software components individually, only the entire app. A full application redeploy is required for each update.
2. **Changes are interconnected:** Changes in one part of the application can have some unexpected effects on the entire project.
3. **Performance issues:** If there is an error or bug in one module, it might accumulate over other servers and there might be a risk of shutting down an entire application.
4. **Lack of flexibility:** Changing frameworks or languages will affect the entire app. This means that to implement better technology, you've got to completely rewrite the whole code base.

4.2. Microservices Architecture

4.2.1.1. Pros of Microservices Architecture

[3] DevOps and microservices work together closely. They are like the main building blocks for continuously delivering software, allowing the app to quickly adjust to what users need and what the business aims for. So, microservices bring a bunch of advantages that can make your digital product better, like:

1. **Updating is straightforward:** You can adjust each part independently, simplifying the process of updating each specific component.
2. **Very reliable:** Making changes to one service doesn't impact others, ensuring high reliability.

3. **Troubleshooting bugs is uncomplicated:** Isolating issues in individual services makes it easy to fix them.
4. **Maintenance is easy:** Introducing or removing features can be done without disrupting the entire code base.
5. **Improved agility and flexibility:** This architecture supports agile practices with small teams that deploy changes frequently.
6. **Customizable tech stack:** Your team can select the technology stack for each microservice individually.

4.2.1.2. Cons of Microservices Architecture [5] Microservices aren't a cure-all solution.

They can pose challenges for a project due to:

1. **Complex development and deployment:** Creating more services and placing them in different locations can be complicated.
2. **Management overhead:** Involving multiple teams may increase complexity and make communication more challenging.
3. **Higher cost:** Each service may have its own expenses for testing, deployment, infrastructure hosting, monitoring, and more.
4. **Harder to test:** Testing individual micro services takes more effort, time, and resources.

1. COMPARITIVE ANALYSIS OF MONOLITHIC AND MICROSERVICES ARCHITECTURE

FEATURE	MONOLITHIC ARCHITECTURE	MICROSERVICE ARCHITECTURE
DESIGN	ALL COMPONENTS FORM A SINGLE UNIT	INDEPENDENT SERVICES THAT CAN BE DEVELOPED AND DEPLOYED INDEPENDENTLY
DEVELOPMENT	EASIER TO DEVELOP AS ALL COMPONENTS ARE BUILT TOGETHER AND SHARE THE SAME CODEBASE	[7]DEVELOPMENT CAN BE MORE COMPLEX DUE TO THE NEED TO MAKE MULTIPLE SERVICES WORK TOGETHER
TESTING	EASIER SINCE ALL COMPONENTS ARE LOCATED IN THE SAME ENVIRONMENT AND INTERACT WITH EACH OTHER	MORE COMPLEX AS THERE ARE MULTIPLE SERVICES THAT NEED TO BE TESTED AND INTEGRATED
DEPLOYMENT	SIMPLER AS THE ENTIRE APPLICATION IS DEPLOYED AS A SINGLE UNIT	SERVICES CAN BE DEPLOYED INDEPENDENTLY, BUT COORDINATING THEIR DEPLOYMENT CAN BE MORE CHALLENGING
MAINTENANCE	CAN BE MORE DIFFICULT TO MAINTAIN AND UPDATE AS THE APPLICATION GROWS IN COMPLEXITY	EASIER TO MAINTAIN AND UPDATE AS EACH SERVICE CAN BE UPDATED AND DEPLOYED INDEPENDENTLY
SCALABILITY	[6]SCALING UP THE APPLICATION REQUIRES SCALING THE ENTIRE SYSTEM, EVEN THE COMPONENTS THAT DON'T REQUIRE ADDITIONAL RESOURCES	YOU CAN SCALE SPECIFIC SERVICES ON DEMAND, ALLOWING FOR MORE EFFICIENT USE OF RESOURCES
FAULT TOLERANCE	A SINGLE ISSUE CAN TAKE DOWN THE ENTIRE SYSTEM	YOU CAN ISOLATE A SPECIFIC ISSUE WITHIN A SEPARATE SERVICE TO FIX IT WITHOUT AFFECTING THE ENTIRE SYSTEM
TECH STACK	ALL APP COMPONENTS USE THE SAME TECH STACK	DIFFERENT SERVICES CAN USE DIFFERENT TECH STACKS

6. CONSIDERATION FOR ARCHITECTURAL CHOICE: MONOLITHIC VS MICROSERVICES

6.1 A CASE TO STAY WITH MONOLITHIC ARCHITECTURE

There are several scenarios where a monolithic architecture is a better choice for your project:

1. [8] Monolithic architecture is well-suited for **smaller applications** that have a limited set of functionalities and require less complexity.
2. When you need to **launch a new product fast** (such as an MVP) to validate your business idea or switch from a legacy system to a modern app without delays.
3. If you would like to provide your users with a **fast app with zero to minimal latency**, as there are no network calls involved between different components.
4. You run a **modular monolithic architecture**, which allows you to segment the code into individual feature modules while preserving a unified structure.

6.2 WHEN TO GO WITH MICROSERVICES ARCHITECTURE

These are the cases that better work for microservices:

1. [9] Microservices are a good choice for **large and complex applications** that have multiple functionalities and require a high level of scalability, reliability, and maintainability.
2. As you **plan to roll out new features often**, the microservice architecture allows adding new functionalities separately in each service without a need to redesign the whole software.
3. In case you **want your development team to be flexible** in their flows, microservices is a good fit as with it they can use various tech stacks for different services within an app and work independently on different services.
4. If you **appreciate resilience**, microservices are your choice to go since a single service failure does not affect the entire system.

1. CONCLUSION

In conclusion, the selection between monolithic and microservices architecture is a crucial decision that should be driven by the specific requirements and objectives of your application. It is paramount to carefully assess the functional and non-functional aspects, as well as the anticipated growth and complexity of the software.

[10] The overarching principle is to avoid the pitfalls of overengineering, which can lead to unnecessary complications and hinder the development process. If the nature of your application does not demand the inherent advantages of a microservices architecture, it is advisable not to impose this structure. On the contrary, if there is foresight that your application will evolve into a more intricate system, it would be unwise to confine yourself to a monolithic approach that might struggle to accommodate future complexities.

Balancing practicality and scalability is the key to ensuring the longevity and success of your application. By aligning your architectural choice with the actual needs of your project, you can optimize development efforts, enhance maintainability, and facilitate seamless scalability when required. The decision-making process should be characterized by thoughtful consideration of the trade-offs involved, ultimately aiming for an architecture that best aligns with both the current and future demands of your application. In this dynamic landscape, adaptability and a keen understanding of your application's unique requirements will guide you toward a well-suited and sustainable architectural choice.

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Theoretical Investigation of Inhibitory Action of Flavanoids against Nipha Virus through Molecular Docking

Discipline: Chemistry

**Joseph Libin K.L.*

**Jibin K. Varughese*

INTRODUCTION

Nipah virus is a bat-borne, zoonotic virus that causes Nipah virus infection in humans and other animals, a disease with a very high mortality rate (40-75%). Numerous disease outbreaks caused by Nipah virus have occurred in South east Africa and South east Asia. Nipah virus belongs to the genus Henipavirus along with the Hendra virus, which has also caused disease outbreaks¹. Nipah virus (NiV) is an RNA virus belonging to family Paramyxoviridae. It belongs to the genus Henipavirus which also contains Hendra virus (HeV) and the recently described Cedar virus. Bats are the natural reservoir of Henipaviruses. It first emerged in Malaysia in 1998 and has since caused several outbreaks in South and Southeast Asia. NiV is highly pathogenic to a broad range of mammals and is considered to have pandemic potential due to its zoonotic as well as person to person transmission². A recent outbreak in a new geographical area in Kerala, India is just the latest such event⁴. Research into this disease has been hampered by the relatively small number of cases as well as difficulties in diagnosis³. Research into epidemiology, modes of transmission and potential prevention and control strategies is needed urgently.

Nipah virus belongs to the family Paramyxoviridae, genus Henipavirus. It is an enveloped, negative-sense, single-stranded RNA virus. The NiV genome is approximately 18.2 kb in length and encodes six structural proteins: nucleocapsid (N), phosphoprotein (P), matrix protein (M), fusion protein (F), glycoprotein (G), and large polymerase protein (L). The virus's envelope is derived from the host cell membrane and contains the F and G proteins, which are essential for viral entry into host cells. The N protein encapsulates the RNA genome, forming a helical ribonucleo capsid complex that associates with the P and L proteins to form the viral replication complex. The M protein plays a crucial role in virus assembly and budding. The F and G proteins facilitate

the initial attachment and fusion of the virus with the host cell membrane, initiating infection^{4,5}.

There had been various efforts to manage NiV infection by searching for small molecule therapeutics against various structural proteins⁶. The virus attachment glycoprotein (NiV-G) present on the virus surface is essential for the recognition of host cell-surface receptors ephrin-B2 (EFNB2) and ephrin-B3 (EFNB3) mediating cellular attachment, followed by some conformational changes that result in triggering of NiV fusion glycoprotein (NiV-F) that leads to membrane fusion and virus entry into host⁷. Hence molecular inhibition of NiV-G is one of the prime strategies for treating NiV infection. Also, as an effective strategy to interrupt virus adhesion with host, the inferences regarding inhibition of interactions between NiV-G and host receptors have been well established, which provide the structural basis for screening antiviral therapeutic inhibitors against NiV-G.

In the current scenario, there is a need to find lead compounds that result in anti-NiV drug development. The entire research conducted in this project makes use of a wide variety of computational methods such as molecular docking, protein-ligand molecular dynamics simulations, post-MD protein-ligand interaction studies^{8,9}, MM-PBSA binding free energy calculations¹⁰, etc. for finding novel flavonoid and flavonoid derivatives inhibitors acting against specific targets of NiV. Due to the disease's complexity, interdisciplinary approaches are generally necessary to address the many components of drug discovery, including resistance, permeability, toxicity, drug efflux, compatibility with other viral therapies, etc. In these situations, computational techniques are highly feasible and adaptable for accelerating the drug development process and effectively tackling challenges at the atomic and molecular levels^{12,15}.

Here we focused on investigating the efficacy of bioactive compounds like flavonoids in inhibiting the NiV-G glycoprotein. Flavonoids are powerful antioxidants and they are found to be effective against diseases such as cancer, obesity, hypertension, and other diseases¹⁶. The literature studies also underline the effectiveness of flavonoids as potential antiviral compounds. In this work, fifty-three hundred (5300) flavonoid phytochemicals and the control drug, were tested for Nipah G protein inhibition potential

through an in silico molecular docking study. Further, drug-like properties of the selected phytochemicals were also evaluated. We combined statistical and pharmacophore approaches to identify functional descriptors responsible for protein–ligand interaction. Finally, the stability of the ligand–protein complex was studied using the molecular dynamic simulation technique²².

Materials and methods

In this study, we sought to find the flavonoid derivative inhibitors against NiV viruses that attach to the crystal structure of NiV-G glycoprotein with PDB ID: 2VSM. The protein crystal structure is a complex of NiV-G glycoprotein with human EFNB2, the crystal structure as shown in Fig: 1



Fig 1. Crystal structure of 2VSM

Protein - Ligand Preparation and Molecular Docking

The initial preparation of the protein PDB structure was carried out by removing water, native inhibitors, complexed protein EFN B-2 and followed by the addition of missing hydrogens and charges. In the case of 2VSM crystal structure, the NAG (2-acetamido-2-deoxy-beta- D-glucopyranose) inhibitor is removed, which is present in binding site. On the addition of missing hydrogens, centroid of the site is located near the catalytic residues GLN559, GLU579, TYR581 and ILE 588 in the crystal the structure was chosen as the docking site of the ligand. The 3D representations of proteins with binding sites of PDB ID : 2VSM is shown in figure 2 and its residue sequence is shown in the figure 3.

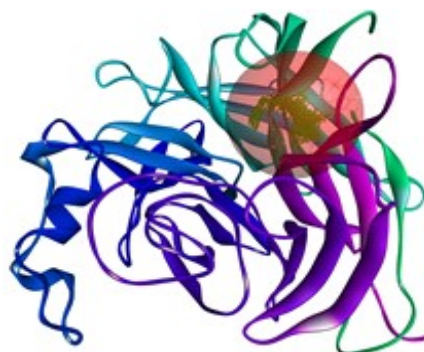


Fig 2. Crystal structure of 2VSM with binding site

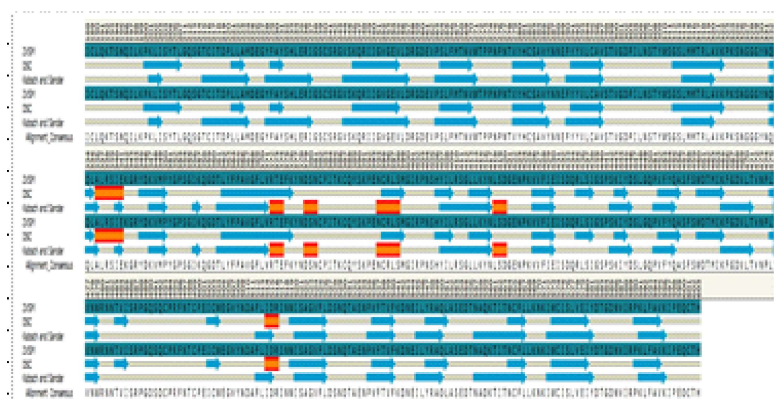


Fig 3. D Sequence of 2VSM

The Cartesian coordinates of the centroid corresponding to the crystal structure of 2VSM was $x = 16.09$, $y = 70.13$ and $z = -24.49$. Grid box centred on these binding site coordinates is utilised for docking calculations. The grid box size for docking were fixed as 40 Å in x, y and z dimensions respectively and the number of grid points per map was 6400. The grid point spacing and exhaustiveness used in the current calculation is 1 Å and 8 respectively. After the each protein-ligand docking calculation, ten conformations (docking poses) and its corresponding docking score was obtained as output³⁰. Out of the ten conformations, the best poses with higher binding energy (docking score) were selected for the further analysis.

Results and discussion

Molecular docking studies

The results of molecular docking of 5 selected flavonoid derivatives (shown in fig 5) to the binding sites of crystal structures of 2VSM is discussed in the following section. The docking scores (binding free energies) of the best docking poses is summarized in Table 1. The 3D representations of best docking poses of these 5 flavonoids in the crystal structures of NiV -2VSM were shown in figure respectively. The images of the docking poses interpret that like the native ligands all the selected flavonoids fit well into the active site of 2VSM crystal structures. As per the docking scoring function of AutoDock¹⁸ the protein-ligand nonbonding interactions (van der Waals / hydrophobic & hydrogen bonding) plays a key role in the effective binding (docking) and contribute significantly to the docking score of a particular pose. The table 2 with 2D images of protein-ligand nonbonding interactions in these best docking poses of 2VSM are also presented here. The 3D docking poses with the interactions of 5 selected 5 ligands inside NiV-2VSM is shown in figure 5 respectively. The freeware Schrodinger Maestro visualizer was used to extract 2D/3D plots from these docking poses. The hydrogen bonding interactions, hydrophobic interactions and all other types of nonbonding interactions between protein and ligands were highlighted in these plot.

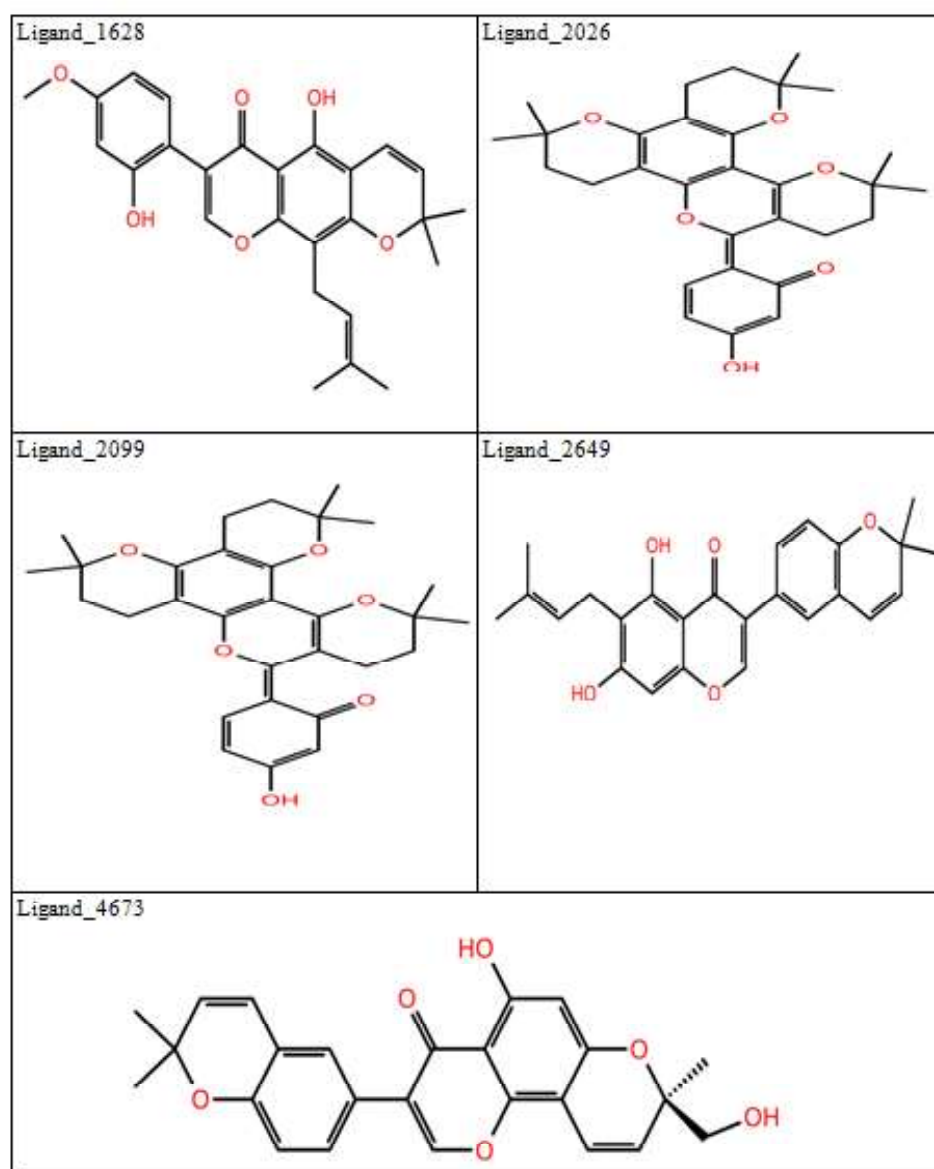


Fig 4. Structure of selected ligands

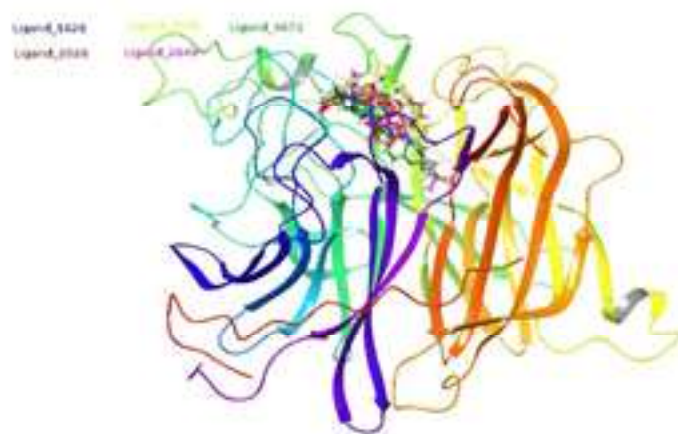
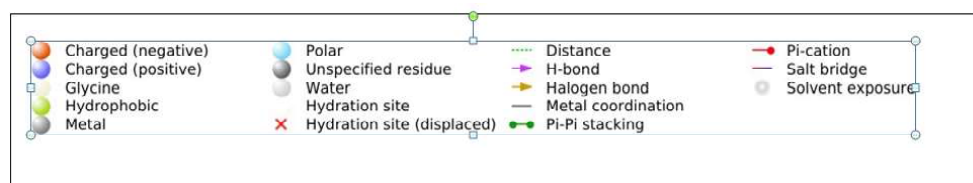


Fig 5. 3D Docked poses of selected ligands at the active site of 2VSM

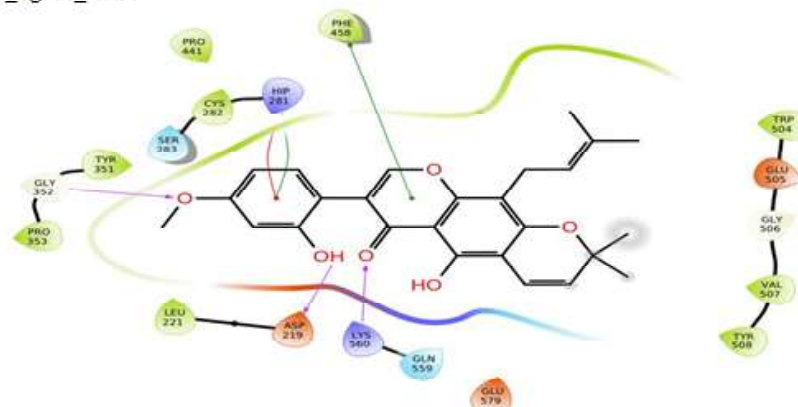
<i>Ligands</i>	<i>Docking Score (kcal/mol)</i>
Ligand_2026	-9.93
Ligand_2649	-9.66
Ligand_1628	-9.48
Ligand_4673	-9.31
Ligand_2099	-8.03

Table 1 Docking scores of selected 8 flavonoids against 2VSM target

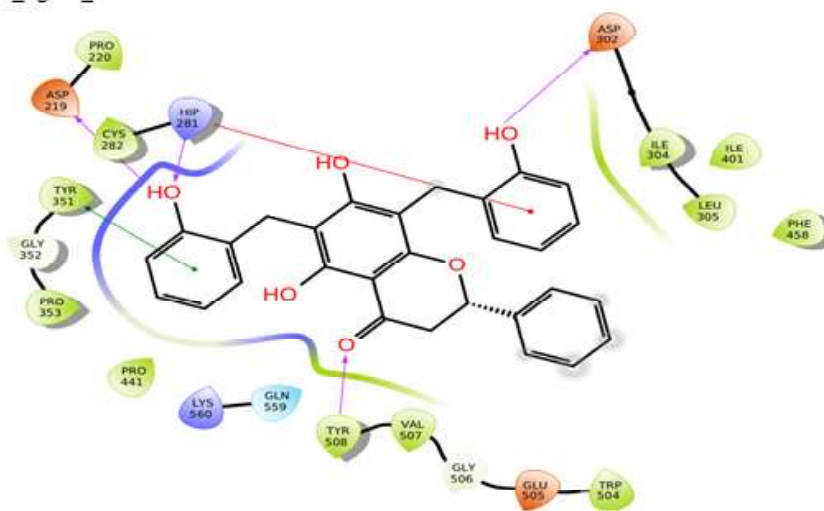
The higher negative binding energy values (docking scores) in all calculations is an indication of effective binding of these flavonoids to the active site of 2VSM crystal structures of NiV. The order of strength of binding of flavonoids to the 2VSM crystal structure is observed as *Ligand_2026* (- 9.93) > *Ligand_2649* (-9.66) > *Ligand_1628* (-9.48) > *Ligand_4673* (-9.31) > *Ligand_2099* (-8.03). On the analysis of the best docking poses (Table 1) all selected flavonoids has binding interactions with the amino acid residues GLN559, GLU579 along with other residues.

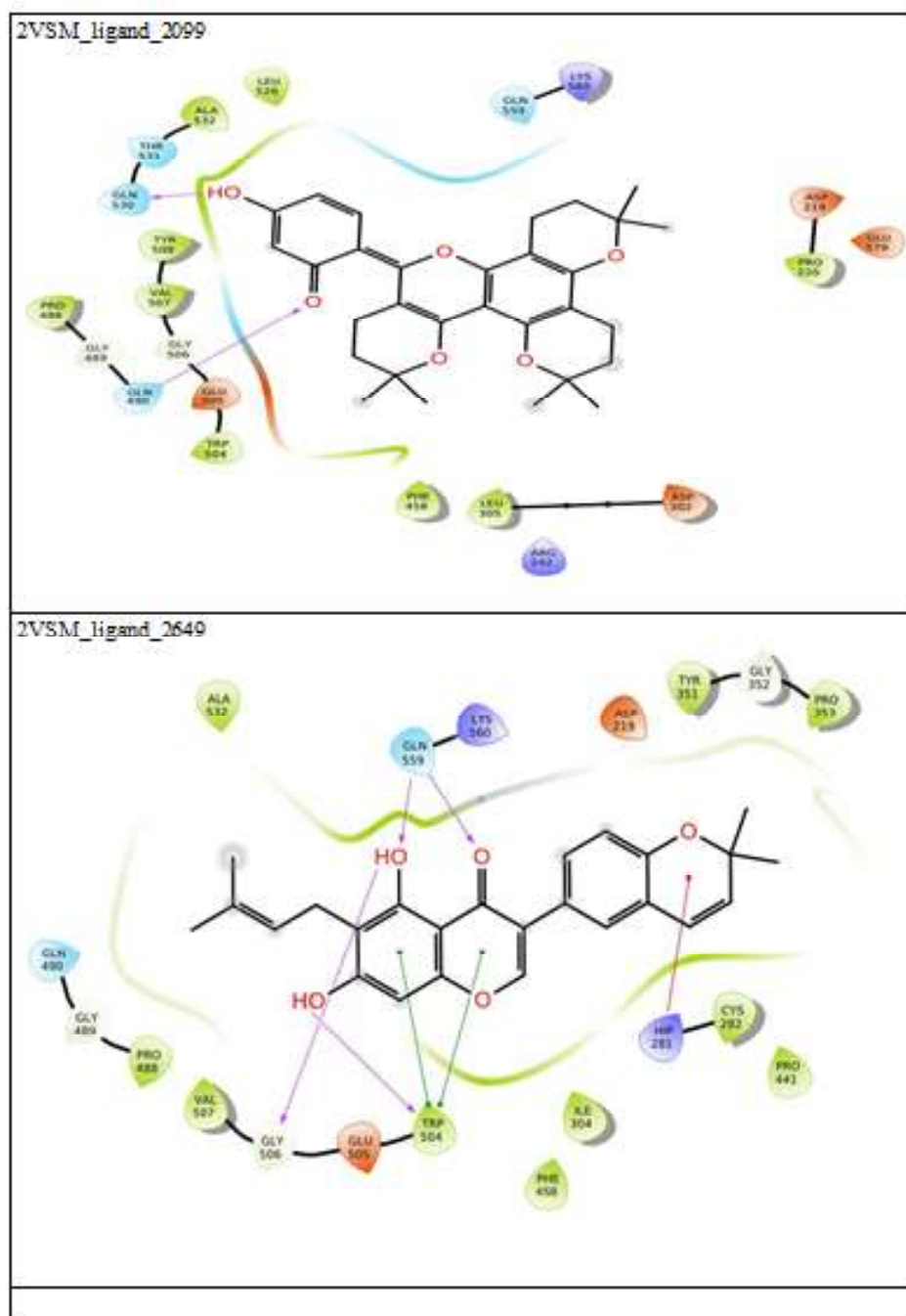


2VSM_ligand_1628



2VSM_ligand_2026





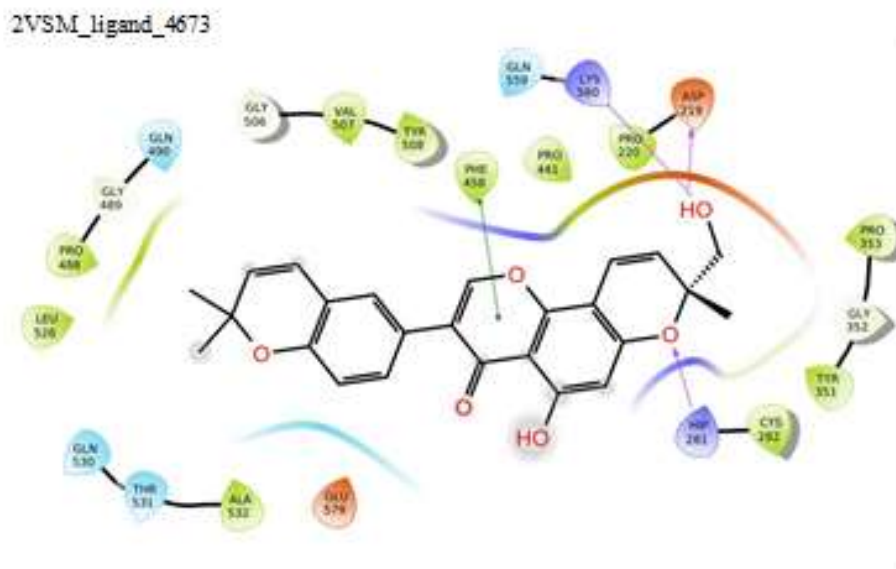


Table 2 : Two dimensional representation of interactions of five selected ligands with 2VSM

We further analysed the nonbonding interactions of each flavonoid with binding site residues of the studied targets. In the analysis of 2VSM-flavonoid docking poses, *Ligand-2026* showed prominent hydrophobic interactions (through van der Waals forces) with amino acid residues including GLN559 (the catalytic residue) including other residues. From the docking results it is confirmed that all selected 5 flavonoids possess bigger negative docking scores (>-8.0 kcal/mol) which is an indication of strong binding affinity of these flavonoids to active site of glycoprotein of NiV. The binding pockets of the flavonoids discussed here have active amino acid residues that reflected the binding sites of the previously reported NAG-2VSM complex. Therefore, these docking poses may be the best option for starting conformations in further molecular dynamics simulation studies.

Conclusion

There are no reported NiV-G inhibitors till date that has been taken into clinical development. From the virtual screening of the few naturally occurring flavonoid compounds using molecular docking calculations we selected 5 flavonoids which has

strong binding affinity and inhibitory activity against NiV-G of NiV. The bigger negative docking scores (>-8.0 kcal/mol) of selected flavonoids at active site NiV-G is an indication of its strong binding affinity and inhibitory activity by reducing its proteolytic activity. We found that the 5 selected flavonoids fit well into the active site domains of NiV-G through strong hydrophobic and hydrogen bonding interactions especially with GLN559 and GLU579 amino acid residues. Since these flavonoids are widely available or synthetically viable, nontoxic and dietary natural compounds with previous history of clinical use, these compounds later subjected to detailed investigations. With this intention, from the docking results, we generated the best docking poses of NiV-G-Flavonoid Complex structures for further MD simulations and post MD investigations. The results obtained from these computational calculations can be extended to experimental studies and the selected flavonoids may choose as lead compounds for the drug discovery of NiV diseases.

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Omnichannel Marketing - Exploring a Marketing Strategy for the Phygital Era

Discipline: Commerce

**Ms. Jomsy Thomas*

**Dr. Raji Mohan*

ABSTRACT

This paper explores the transformative role of omnichannel marketing in the contemporary business landscape amidst Industry 4.0. With digitalization, connectivity, and advanced analytics reshaping industries, omnichannel marketing emerges as a crucial strategy for enhancing customer engagement and driving business growth. By seamlessly integrating online and offline channels, omnichannel marketing allows companies to provide a consistent brand experience, thereby fostering customer loyalty and expanding their customer base. Drawing insights from the evolution of marketing approaches and industry trends, this paper highlights the significance of omnichannel marketing in meeting the dynamic needs of consumers and staying competitive in today's rapidly evolving market environment.

Key Words: Omnichannel Marketing, Digitalization, Customer Engagement, Marketing Strategies.

Introduction

In this era of Industry 4.0, which is providing more importance to digitalization, connectivity, and advanced analytics, the adoption of technology-driven marketing, is essential for every industrial sector. This era is defined by digital transformation and rapid market shift. As the customer is always looking for new ways to access information, the manufacturers and retailers found new ways to adopt a mixed marketing strategy for enhanced customer experience. Omni-channel marketing emerged as a customer-centric marketing approach. Omnichannel marketing is the integration and cooperation of the various channels both online like websites and offline like stores to interact with consumers. The major goal of this marketing approach is consistent brand experience. A blend of physical and digital channels is referred to as "phygital". An omnichannel strategy may offer consumers the freedom to find and purchase

online, in-store, or a combination thereof - such as “buy online and pick up in-store” (BOPIS). Today, organizations across industries are leveraging omnichannel strategies, including healthcare, retail, finance, technology, and more. Through the adoption of an omnichannel marketing strategy companies can create a convenient, seamless user experience for consumers thereby they can enhance their business performance through customer retention and customer base expansion. This paper is an effort to introduce the concept of Omnichannel marketing and how this marketing strategy is usefully adopted for building customer loyalty and expanding the customer base.

The Concept of Omnichannel Marketing

Literature (Hue 2023) suggests that the term ‘Omnichannel’ was introduced in the world of marketing in 2010. In 2013 this term became a “Buzz word” (Louie 2015; Hue 2023). The Latin term “Omni” indicates “all” or “every” (Briel, 2018; Vishnukanth et al.2024). Omni-channel is defined as “a coordinated multi-channel offering that provides a seamless experience when using all of the retailer’s shopping channels” (Levy et al., 2013; Manel 2019).

According to the Universal Marketing Dictionary omnichannel marketing is explained as “the strategic integration of all the possible points of contact between customers/prospects and the marketer and/or marketer’s products”. These include the channels for media (including social media), sales, distribution, and customer support.

Thus, Omnichannel marketing involves the collaboration of all the available channels to allow customers to be aware of the products and services rendered and make them feel that they are always surrounded and informed by their favourite brands. This strategy aims to ensure a seamless and consistent brand experience for their customers through various online and offline channels. The omni channel marketers always trying to be spotted by their potential customers anytime and every time with multiple options. These options include online purchases, in-store shopping, or a combination of both.

The emergence of the ‘Low-cost digital era and the tagline of Covid 19 pandemic - Social distancing’ blurred the line between online and offline shopping.

People all over the world enjoyed the relaxed shopping experience rendered by the ‘mouse click and finger touch’. After the pandemic when the doors and gates of the world became wide open, people preferred to move out and enjoy the missed physical shopping experience. This demanded firms in adoption of the traditional brick-and-mortar system for engaging their customers. This necessitates the firms to adopt and adapt the concept of Omnichannel Marketing for their customer retention and expansion, which will make the customers engaged with the brand. While traditional multichannel marketing channels operate in silos with distinct strategies, omnichannel marketing aims for channel interconnectivity. It creates a unique experience across digital and physical platforms that ensures customers interact with brands seamlessly, whether they are browsing online, shopping in-store, or engaging on social media.



Figure 1

Source: Universal Marketing Directory (from x-cart.com)

A Journey from Multi-Channel to Cross Channel to Omnichannel

The evolution of an interconnected society through digital transformation highly demanded an evolution of an interconnected marketing approach. The companies are adopting three different approaches to stay connected with their customers. These can be categorized into 1. Multi-channel marketing, 2. Cross channel Marketing 3. Omnichannel Marketing (Marine Aubagna.,2020)

Multichannel Approach - When the internet became a popular method for buying journeys, the companies, in the early stage adopted the concept of multi-channel marketing. In multi-channel marketing, the consumers were able to communicate and purchase from companies using different channels viz e-commerce, personal shopping, mail orders, m-commerce, etc. But in this approach, each channel will be disconnected and will not collaborate. Each channel needs its own strategy. (Marine Aubagna.,2020) This concept is more or less product-oriented.

Cross-channel Approach – To overcome the limitation of less interconnectivity in the multichannel approach, a more integrated method, cross-channel marketing, was introduced as an advancement. (Marine Aubagna.,2020) Cross-channel support and channel integration will help the customers to switch between channels seamlessly during their journey towards purchasing a product.

Omnichannel Approach- Even though cross-channel marketing allows an integrated customer experience, a more integrated and advanced marketing option, which allows back-and-forth communication, (Marine Aubagna.,2020), was introduced via the omnichannel approach. These channels are working seamlessly, and often parallelly to enhance customer experience. Omni channel is purely meant for enhancing customer engagement (Verhoef et al., 2009; Verhoef et al., 2015; Yrjölä, M., Saarijärvi, H., & Nummela, H.,2018). Thus, Omnichannel marketing provides a holistic view of all channels involved in the customer purchase journey (Brynjolfsson et al., 2013; Yrjölä, M., Saarijärvi, H., & Nummela, H.,2018).

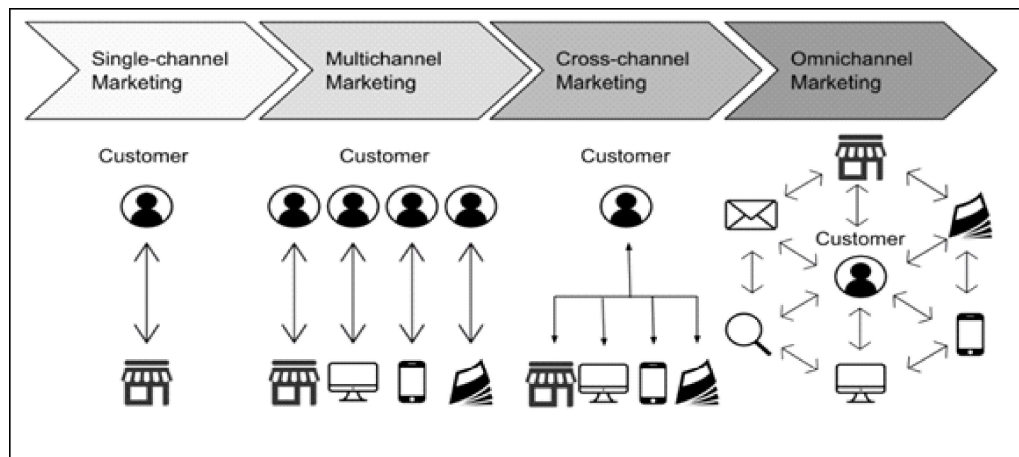


Figure 2

Source: Direct Marketing Association

Importance of adoption of Omnichannel marketing.

To cope with the surging demand for easy access to products and services, many multinational companies are adopting omnichannel marketing as their business model. To fit the new marketing environment of going for phygital companies irrespective of their origin, size, and place need to adopt a more working model to ensure customer retention. (Ya-Jun Cai, Chris K. Y. Lo., 2020). Research shows that customers are now willing to use different channels for their purchasing journey as they have more access to digital platforms. (Silva et al., 2018). In omnichannel marketing, customer interaction and the active presence of customers are focused to a large extent. Customers are interested in being actively involved in their purchase process (Silva et al., 2018; Monika Hajdas, Joanna Radomska, Susana C. Silva., 2022). Developing economies like India and China are showing high encouragement through more engagement of online customers, and online purchases upsurge to a \$3.9 trillion value (WEF, 2020; Sudhanshu & Manu; (2023). To build long-term customer loyalty, companies need to give the customers a feel of their presence. they need to engage the customers effectively. This is where the omnichannel marketing strategy wins its place.

The digital adoption by retailers and the advent of internet usage always keep customers informed about the market. But studies (Park & Lee, 2017; Chatterjee & Kumar, 2017; Sudhanshu & Manu, 2023) show the purchase action will happen according to the convenience of the consumer. The omni-channel adoption will support retailers to ensure their customers complete their shopping journey more conveniently and comfortably.

In addition to this, as a channel marketing strategy is highly integrated, by implementing this, companies can provide a consistent and personalized experience to customers, regardless of the channel they choose to engage with. This approach helps to avoid channel conflict and cannibalization by ensuring that each channel has a unique value proposition and contributes to overall sales growth (Beth Owens, 2023).

The omni-channel experience in the banking sector enhanced the brand loyalty of the customers. (Quynh Tran Xuan, Hanh T.H. Truong & Tri Vo Quang. ;2023). Studies suggest that establishing and maintaining relationships with existing customers enhances the firm's overall business performance and profitability. This will reduce the cost of the firm to a large extent. Brand familiarity generated by the Omni channel will result in the ultimate business performance of the firm. (Hickman, E., Kharouf, H. & Sekhon, H.;2019).

Real-World Examples of Omnichannel Success

Several companies have successfully implemented omnichannel strategies that significantly enhance customer engagement and customer loyalty by integrating multiple touchpoints for a seamless shopping experience.

Starbucks: Starbucks has created a highly personalized customer experience by integrating its mobile app with its physical stores, offering personalized promotions, mobile ordering, and rewards systems. Starbucks demonstrates how digital tools can effectively complement in-store experiences with 24% of U.S. transactions made through the app, leading to increased customer engagement and loyalty (Serrano, 2022; *The Power of Omnichannel Marketing*, n.d.).

Nike: Nike through its mobile app creates a seamless connection between online and in-store experiences to enhance their customer journey. Features like personalized product recommendations, virtual try-ons, and the integration of fitness tracking offer a highly engaging and immersive customer experience across channels, which has helped to boost customer satisfaction (*Customer Experience (CX) at Nike: A Case Study in Excellence*, n.d.) Nike's omnichannel approach underscores how technology can create a cohesive brand experience across multiple platforms, strengthening customer relationships.

The Role of Industry 4.0 in Omnichannel Marketing

Industry 4.0, powered by advancements such as the Internet of Things (IoT), artificial intelligence (AI), and big data, has revolutionized marketing approaches. These technologies allow businesses to gather and analyse customer data in real-time, which facilitates personalized interactions across channels. For example, IoT-enabled devices monitor consumer behaviours, offering insights for the prediction of preferences and purchasing patterns of consumers. This will allow businesses to anticipate needs and tailor communications accordingly. (Bharadwaj et al., 2013).

Additionally, big data and machine learning play crucial roles in advancing omnichannel marketing. These technologies help companies in processing vast amounts of data from multiple channels, leading to more accurate predictions of consumer behaviour. With predictive analytics, businesses can enhance customer targeting and deliver a more tailored, cohesive, and seamless shopping experience.

Challenges and Future Directions in Omnichannel Marketing

Despite omnichannel marketing offers significant advantages, putting it into practice can be challenging. One of the most prominent issues is channel cannibalization. Channel cannibalization refers to one channel's growth coming at the expense of another. Companies need to ensure that each channel has a distinct value proposition and integrates harmoniously with the others to combat this (Calvo et al., 2023).

In addition, maintaining consistency and uniformity across all channels can be difficult for businesses with complex global operations. However, the integration of AI

and advanced analytics can help mitigate this challenge. For that, they should provide real-time insights and facilitate better decision-making processes (Silva et al., 2018).

Looking forward, omnichannel marketing is expected to evolve and advance to provide ever more engaging purchasing experiences with the integration of virtual reality (VR) and augmented reality (AR). This will enable even more immersive shopping experiences. The rise of the metaverse will also provide additional chances for marketers and brands to create interactive, virtual shopping environments, that will further enhance customer engagement and retention.(Post, 2024).

Conclusion

Omni Channel marketing is the effort of the marketer to make his product anywhere and anytime as and when it attracts the attention of the prospective customer. To make awareness about your brand is one of the important objectives of every seller as the world becomes a single market. As your prospective customer is carrying the entire market in a small ‘dabba’ in his pocket with wireless connectivity you can reach the attention through all five senses. There comes the role of omni-channel marketing. To grab the attention of consumers first, then be present and available as and when they need to remind about your product and brand and thereby enhance the customer experience. Your prospective consumer will be your brand promoters. This is the motto of omnichannel marketing.

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